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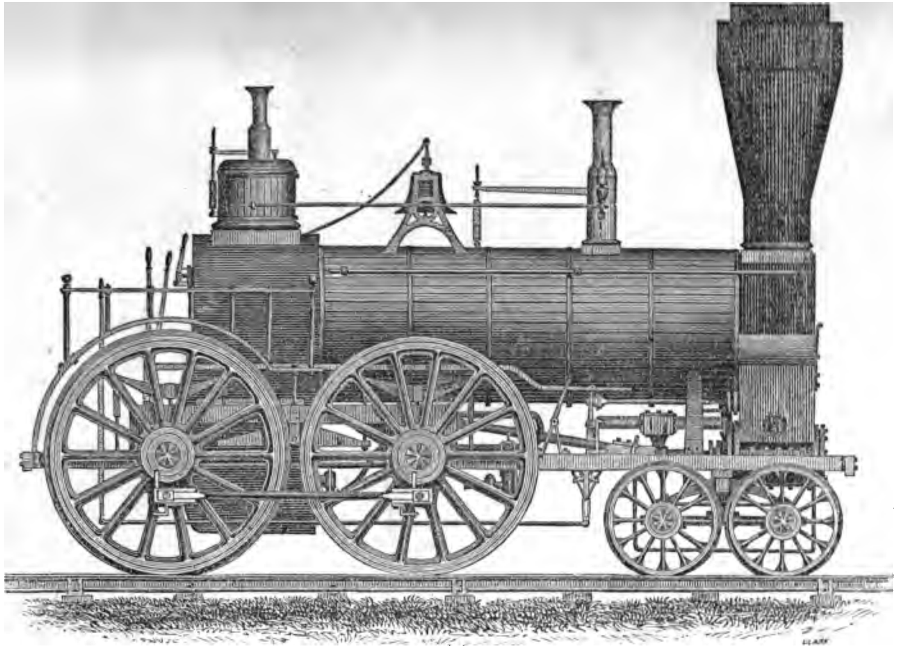

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TO THE

Hon. SAMUEL ATKINS ELIOT,

MAYOR OF THE CITY OF BOSTON, AND CHAIRMAN OF THE SCHOOL COMMITTEE.

Sir,

The Public Schools of this city are under many obligations to you, for the interest you have taken in them, and for your disinterested exertions for their improvement. This volume, designed to supply a want which they have long felt, affords an opportunity of acknowledging the obligation, which I gladly embrace. The gratification which I feel in seeing you at the head of our municipal institutions, I beg leave to express in borrowed language:—

Tibi ut gratuler non est in animo; sed contra, hanc occasionem, mihi sic oblatam, nostram civitatem gratulandi, reniti non possum. Quæ omnia solita tua benevolentia ut accipias quæso.

I am, Sir, very respectfully,

Your obedient Servant,

RICHARD GREEN PARKER

Entered, according to Act of Congress, in the year 1848.
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PREFACE.

THE School Committee of the city of Boston having recently furnished the Grammar Schools with apparatus for exemplifying the principles of Natural Philosophy; the author of this work, who, for twenty years, has been at the head of one of these large establishments, and has felt the want of an elementary treatise *unencumbered with extraneous matter*, has been induced to attempt to supply the deficiency. If he is not deceived in the result of his labors, the work will commend itself to notice by the following features:

1. It is adapted to the *present state* of natural science; embraces a wider field, and contains a greater amount of information on the respective subjects of which it treats, than any other elementary treatise of its size.

2. It contains engravings of *the Boston School set of philosophical apparatus;* a description of the instruments, and an account of many experiments which can be performed by means of the apparatus.

3. It is enriched by a representation and a description of the *Locomotive* and the *Stationary Steam Engines*, in their latest and most approved forms.

4. Besides embracing a copious account of the principles of Electricity and Magnetism, its value is enhanced by the introduction of the science of Pyronomics, together with the new sciences Electro-Magnetism and Magneto-Electricity.

5. It is peculiarly adapted to the convenience of study and of recitation, by the figures and diagrams being first placed side by side with the Illustrations, and then repeated on separate leaves at the end of the volume. The number is also given, where each principle may be found, to which allusion is made throughout the volume.

6. It presents the most important principles of science in a larger type; while the deductions from these principles, and the illustrations, are contained in a smaller letter Much useful and interesting matter is als

crowded into notes at the bottom of the page. By this arrangement, the pupil can never be at a loss to distinguish the parts of a lesson which are of primary importance; nor will he be in danger of mistaking theory and conjecture for fact.

7. It contains a number of original illustrations, which the author has found more intelligible to young students, than those with which he has met elsewhere.

8. Nothing has been omitted which is usually contained in an elementary treatise.

A work of this kind, from its very nature, admits but little originality. The whole circle of the sciences consists of principles deduced from the discoveries of different individuals, in different ages, thrown into common stock. The whole, then, is common property, and belongs exclusively to no one. The merit, therefore, of an elementary treatise on natural science must rest solely on the judiciousness of its selections. In many of the works from which extracts have been taken for this volume, the author has found the *same language* and expressions without the usual marks of quotation. Being at a loss, therefore, whom to credit for some of the expressions which he has borrowed, he subjoins a list of the works to which he is indebted, with this general acknowledgment; in the hope that it may be said of him as it was once said of the Mantuan Bard, that "he has *adorned* his thefts, and polished the diamonds which he has stolen."

It remains to be stated, that the Questions at the bottom of the page, throughout the volume, were not written by the author, but were prepared by another hand.

R. G. P

BOSTON, *March*, 1848.

ADVERTISEMENT

TO THE SEVENTEENTH EDITION

TEN years have elapsed since this work first appeared in permanent form from the hands of the stereotyper. During this time, the author has been gratified to learn that sixteen editions have been called for by the public; but this gratification has been mingled with regret that he has been unable from time to time to make such improvements as he knew were needed, and which the progress of science, as well as a more extended experience, seemed imperiously to demand. He gladly avails himself of the present opportunity, afforded by the new publishers into whose hands it has fallen, to make such improvements as in his opinion will render it more worthy of the liberal patronage it has received; for although it is a long time since the author has had any pecuniary interest in the work, he hopes that it is not true that he has had "no further solicitude."

The necessity of a revision of the work at this time will appear from the following statement. By a vote of the School Committee of Boston in 1836, a certain portion of philosophical apparatus was introduced into the Grammar Schools, as an experiment. The apparatus was designed to unite economy with simplicity, and was confined to the departments of Pneumatics and Electricity. To this apparatus the book was specially adapted, though not wholly confined. By a recent vote of the Committee, (August, 1847,) apparatus of superior construction, and embracing a much wider field, was substituted for the cheap and defective sets that were at first introduced. It becomes necessary, therefore, in a volume prepared with special reference to the wants of the Boston schools, to have regard to the construction and the character of the instruments by which the principles of physical science are illustrated in these large establishments; the author has therefore deemed it expedient to make such a revision of the whole work, as will not only render it a convenient manual to accompany the new apparatus, but also embrace the recent improvements and discoveries by which the branches of science of which it treats have been enriched. A schedule of the new apparatus is subjoined; and the author indulges the expectation that the present edition of this work will be found more worthy than its predecessors of the favor which the public have bestowed upon it.

Lilac Lodge,
Dedham, *October*, 1847.

LIST OF WORKS

WHICH HAVE BEEN CONSULTED, OR FROM WHICH EXTRACTS HAVE BEEN TAKEN, IN THE PREPARATION OF THIS VOLUME.

Annals of Philosophy; Arnott's Elements of Physics; Bigelow's Technology; Cambridge Physics; Chambers' Dictionary; Enfield's, Olmsted's, Blair's, Bakewell's, Draper's, Grund's, Jones', Comstock's, and Conversations on Natural Philosophy; Davis' Manual of Magnetism; Encyclopædia Americana; Franklin's Philosophical Papers; Henry's Chemistry; King's Manual of Electricity; Lardner on the Steam Engine; Library of Useful Knowledge; Paxton's Introduction to the Study of Anatomy; Pambour on Locomotive Engines on Railways; Peschel's Elements of Physics; Philips' Astronomy; Sir John Herschel's Astronomy; Silliman's Journal of Science; Singer's Electricity; Scientific Class Book; Scientific Dialogues; Smith's Explanatory Key; The Year Book; Turner's Chemistry; Wilkins' Astronomy; Worcester's and the American School Geography; Lathrop, McIntire, and Keith on the Globes.

SCHEDULE OF PHILOSOPHICAL APPARATUS FOR THE BOSTON GRAMMAR SCHOOLS.*

Adopted by the School Committee, August, 1847.

LAWS OF MATTER.

Apparatus for illustrating Inertia.
Pair of Lead Hemispheres, for Cohesion.
Pair of Glass Plates, for Capillary Attraction.

LAWS OF MOTION.

Ivory Balls on Stand for Collision.
Set of eight Illustrations for Centre of Gravity
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Complete set of Mechanicals, consisting of Pulleys; Wheel and Axle; Capstan; Screw; Inclined Plane; Wedge.

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Mounted Spirit Level.
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Scales and Weights, for Specific Gravity.
Hydrostatic Bellows, and Paradox.

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Lifting, or Common Water-pump.
Forcing Pump; illustrating the Fire-engine.
Glass Syphon-cup; for illustrating intermitting Springs.
Glass and Metal Syphons.

PNEUMATICS.

Patent Lever Air-pump and Clamp.
Three Glass Bell Receivers, adapted to the Apparatus.
Condensing and Exhausting Syringe.
Copper Chamber for Condensed Air Fountain.
Revolving Jet and Glass Barrel.
Fountain Glass, Cock, and Jet for Vacuum.
Brass Magdeburg Hemispheres.

---

* The cost of this apparatus is about two hundred and sixty dollars. It was made by Mr. Joseph M. Wightman, No. 33 Cornhill, Boston, and in an eminent degree unites beauty with durability.

Improved Weight-lifter, for upward pressure.
Iron Weight of fifty-six pounds and strap, } for Weight-lifter.
Flexible Tube and Connectors, }
Brass Plate and Sliding Rod.
Bolt Head and Jar.
Tall Jar and Balloon.
Hand and Bladder Glasses.
Wood Cylinder and Plate.
India-rubber Bag, for expansion of air
Guinea and Feather Apparatus.
Glass Flask and Stop-cock, for weighing air.

ELECTRICITY.

Plate Electrical Machine.
Pith-ball Electrometer.
Electrical Battery of four Jars.
Electrical Discharger.
Image Plates and Figure.
Insulated Stool.
Chime of Bells.
Miser's Plate, for shocks.
Tissue Figure, Ball and Point.
Electrical Flyer and Tellurian.
Electrical Sportsman, Jar and Birds.
Mahogany Thunder-house and Pistol.
Hydrogen Gas Generator.
Chains, Balls of Pith, and Amalgam.

OPTICS.

Glass Prism, and pair of Lenses.
Dissected Eyeball, showing its arrangement

MAGNETISM.

Magnetic Needle on Stand.
Pair of Magnetic Swans.
Glass Vase for Magnetic Swans.
Horseshoe Magnet.

ASTRONOMY.

Improved School Orrery.
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ARITHMETIC AND GEOMETRY.

Set of thirteen Geometrical Figures of Solids.
Box of sixty-four one-inch Cubes, for Cube Root, &c.

AUXILIARIES.

Tin Oiler; Glass Funnel; Sulphuric Acid
Set of Iron Weights for Hydrostatic Paradox.

CONTENTS.

CHAPTER I.

Divisions of the subject

CHAPTER II.

Of Matter

CHAPTER III.

Of Gravity

CHAPTER IV.

Mechanics, or the Laws of Motion

CHAPTER V.

Hydrostatics

CHAPTER VI.

Hydraulics

CHAPTER VII.

Pneumatics

CHAPTER VIII

Acoustics

CHAPTER IX.

Pyronomics

CHAPTER X.

Page
Optics 150

CHAPTER XI.

Electricity 192

CHAPTER XII.

Galvanism, or Voltaic Electricity 216

CHAPTER XIII.

Magnetism and Electro-Magnetism 230

CHAPTER XIV.

Astronomy 257

INTRODUCTION.

The term Philosophy literally signifies, the love of wisdom; but, as a general term it is used to denote an explanation of the reason of things, or an investigation of the causes of all phenomena, both of mind and of matter.

When applied to any particular department of knowledge, the word Philosophy implies the collection of general laws or principles, under which the subordinate facts or phenomena relating to that subject are comprehended. Thus, that branch of Philosophy which treats of God, his attributes and perfections, is called Theology;* that which treats of the material world is called Physics, or Natural Philosophy; that which treats of man as a rational being, is called Ethics, or Moral Philosophy; and that which treats of the mind is called Intellectual Philosophy, or Metaphysics.†

---

* The word Theology is derived from two Greek words, the former of which (Θεος) signifies God, and the latter (λογος) means a discourse; and these two words combined in the term *Theology*, literally imply a discourse about God. The latter of these two Greek words (λογος or logos) is changed into *logy* to form English compounds, and it enters into the composition of many scientific terms. Thus, we have the words mineral*ogy*, the science of minerals; meteoro*logy*, the science which treats of meteors; ichthyo*logy*, the science of fishes; entomo*logy*, the science of insects; litho*logy*, of stones; concho*logy*, of shells, &c.

† The word Metaphysics is composed of two Greek words, Meta, (or μετα,) which signifies *beyond*, and phusis, (or φυσις,) which signifies *nature*, and in composition these words imply something *beyond nature*. From

The terms, art and science, have not always been employed with proper discrimination. In general, an art is that which depends on practice or performance, while science is the examination of general laws, or of abstract and speculative principles. The theory of music is a science; the practice of it is an art.

Science differs from art in the same manner that knowledge differs from skill. An artist may enchant us with his skill, although he is ignorant of all scientific principles. A man of science may excite our admiration by the extent of his knowledge, though he have not the least skill to perform any operation of art. When we speak of the mechanic arts, we mean the practice of those vocations in which tools, instruments, and machinery are employed. But the science of mechanics explains the principles on which tools and machines are constructed, and the effects which they produce. Science, therefore, may be defined, a collection and proper arrangement of the general principles or leading truths relating to any subject; and there is this connection between art and science, namely—"A principle in science is a rule of art."

NATURAL PHILOSOPHY

CHAPTER I.

DIVISIONS OF THE SUBJECT.

1. NATURAL PHILOSOPHY is the science which treats of the powers and properties of natural bodies, their mutual action on one another, and the laws and operations of the material world.

2. Some of the principal branches of Natural Philosophy are, Mechanics, Pneumatics, Hydrostatics, Hydraulics, Acoustics, Pyronomics, Optics, Astronomy, Electricity, Galvanism,* Magnetism, Electro-Magnetism, and Magneto-Electricity.

1. Mechanics is that branch of Natural Philosophy which relates to motion and the moving powers, their nature and laws, with their effects in machines, &c.

2. Pneumatics treats of the nature, properties, and effects of air.

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* It may perhaps be questioned whether the subjects of Galvanism, Electro-Magnetism, and Magneto-Electricity, do not more properly fall within the province of Chemistry, as they describe effects dependent on chemical action. As this volume is designed for the diffusion of useful information, a strict adherence to rigid classification has not been deemed so important, as to exclude the notice of subjects so intimately connected with one of the most interesting branches of Natural Philosophy.

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1. What is Natural Philosophy?

2. What are the principal branches of Natural Philosophy? What is Mechanics? Of what does Pneumatics treat?

3. Hydrostatics treats of the nature, gravity, and pressure of fluids.

4. Hydraulics treats of the motion of fluids, particularly of water; and the construction of all kinds of instruments and machines for moving them.

5. Acoustics treats of the nature and laws of sound.

6. Pyronomics treats of heat, the laws by which it is governed, and the effects which it produces.

7. Optics treats of light, of color, and of vision, or sight.

8. Astronomy treats of the heavenly bodies, such as the sun, moon, stars, comets, planets, &c.

9. Electricity treats of thunder and lightning, and the causes by which they are produced, both naturally and artificially.

10. Galvanism is a branch of Electricity.

11. Magnetism treats of the properties and effects of the magnet, or loadstone.

12. Electro-Magnetism treats of Magnetism induced by Electricity.

13. Magneto-Electricity treats of Electricity induced by Magnetism.

CHAPTER II.

OF MATTER* AND ITS PROPERTIES.

3. Matter is the general name of every thing that occupies space, or has figure, form, or extension.

* The ancient philosophers supposed that all material substances were composed of Fire, Air, Earth, and Water, and these four substances were called the four elements, because they were supposed to be the simple substances of which all things were composed. Modern science has proved that not one of these is a simple substance, but that there are at least fifty-five simple substances, thirty-two of which are metallic and twenty-four non-metallic. The consideration of those substances which enter into the composition of all matter, in whatever form, belongs to

---

Of what does Hydrostatics treat? Hydraulics? Acoustics? Pyronomics? Optics? Astronomy? Electricity? Of what is Galvanism a branch? Of what do Magnetism treat? Electro-Magnetism? Magneto-Electricity?

3. What is Matter?

4. There are seven essential properties belonging to all matter, namely: 1. Impenetrability, 2. Extension, 3. Figure, 4. Divisibility, 5. Indestructibility, 6. Inertia, and 7. Attraction.

1. These are called essential properties, because no particle of matter can be deprived of them, or exist without them.

2. There are certain other properties existing in different bodies, called accidental properties, because they do not necessarily exist in the bodies themselves, but depend upon their connection with other bodies. Thus, color and weight are accidental properties, because they do not necessarily exist in the bodies that possess them, but depend upon their connection with other things.

3. There are also certain terms used to express the state in which matter exists, such as Porosity, Density, Rarity, Compressibility, Expansibility, Mobility, Elasticity, Brittleness, Malleability, Ductility, and Tenacity.

5. Impenetrability is the power of occupying a certain space, so that where one body is, another cannot be, without displacing it.

1. Impenetrability belongs to fluids as well as solid bodies. The reason why fluids appear less impenetrable than solid bodies, is, that the particles of which they are composed move

---

the science of Chemistry. Bodies which consist of one simple substance are called *homogeneous*, while those which consist of two or more simple substances are called *heterogeneous*. Thus, water is a heterogeneous substance, being composed of two simple or homogeneous aeriform fluids, called Hydrogen and Oxygen. An aeriform fluid is a fluid in the form of air. When the particles of which matter is composed is mentioned, it is to be understood that the smallest imaginable portion is meant, not of the homogeneous substances of which it may be composed, but of the matter itself, whether homogeneous or heterogeneous.

---

4. How many essential properties of matter are there? What are they? Why are they called essential properties? What other properties exist in different bodies? Why are they called accidental properties? Are color and weight essential or accidental properties? Why? What terms are used in Philosophy to express the state in which matter exists?

5. What is meant by Impenetrability? Does impenetrability belong to fluids? Why do fluids appear less impenetrable than solid bodies? What is supposed to be the form of the particles of fluids?

easily among themselves, on account of their slight degree of cohesion.*

2. Put some water into a tube closed at one end; and then insert a piece of wood that fits closely the inside of the tube. It will be impossible to force the wood to the bottom of the tube, unless the water be first removed. The same experiment may be made with air instead of water; and proves that water, air, and all other fluids are equally solid, or impenetrable, with the hardest bodies.

3. The impenetrability of water was shown by an experiment made at Florence many years ago. A hollow globe of gold was filled with water, and submitted to great pressure. The water was seen to exude through the pores of the gold, and covered it with a fine dew.

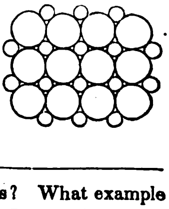
4. When an open vial, not inverted, is plunged into a basin of water, the air will rush out in bubbles, to make room for the water; and if an inverted tumbler or goblet be immersed in water, the water will not rise far in the tumbler unless it be inclined so that the air can escape. These are further proofs of the impenetrability of air.

5. When a nail is driven into wood, or any other substance, it forces the particles asunder, and makes its way between them; and the wood is not increased in size by the addition of the nail, because wood is a porous substance, the particles of which may be compressed, and thus make way for the nail.

---

* It is a well-known fact, that a certain quantity of salt, the particles of which are supposed to be smaller than those of water, can be put into a vessel full of water, without causing it to overflow; and as the particles of which sugar is composed are smaller than those of salt, a portion of sugar may be added after the fluid is saturated with salt. This may be accounted for by supposing that the particles of fluids are round, and therefore touch one another only in a few points. There will be spaces between the particles in the same manner that there are between large balls which are piled on one another. Between these spaces other smaller balls may be placed; and these smaller balls, having spaces between them, will admit others still smaller, as may be seen in Fig. 1.

Fig. 1.



What follows from this? What figure illustrates this? What example can you give to prove the impenetrability of water? What of the air? What of solids?

6. Extension is but another name for bulk, or size; and it is expressed by the terms length, breadth, width, height, depth, and thickness.*

7. Figure is the form or shape of a body. Two circles or two balls may be of the same shape or figure, while they differ in extension. The limits of extension constitute figure.

8. Divisibility is susceptibility of being divided. To the divisibility of matter there is no known limit.

1. A single grain of gold may be hammered by a gold-beater until it will cover fifty square inches; each square inch may be divided into two hundred strips; and each strip into two hundred parts. One of these parts is only *one two-millionth* part of a grain of gold, and yet it may be seen with the naked eye.

2. The particles which escape from odoriferous objects also afford instances of extreme divisibility.

9. By the Indestructibility of matter is meant that it cannot be destroyed. It may be indefinitely divided, or altered in its form, color, and accidental properties, but it must still continue to exist in some form through all its changes of external appearance.

1. When water disappears, either by boiling over a fire, or

---

* Length is the extent from end to end. Breadth or width is the extent from side to side. Height, depth, or thickness, is the extent from the top to the bottom. The measure of a body from the bottom to the top is called height; from the top to the bottom is called depth. Thus we speak of the depth of a well, the height of a house, &c.

---

6. What is meant by Extension? What terms are used to express the size of a body? What is length? Breadth? Height, depth, or thickness? What is the difference between height and depth?

7. What is meant by Figure? May bodies be of the same shape or figure and of different dimensions? Give an example. What constitutes figure?

8. What is meant by Divisibility? Is there any known limit to the divisibility of matter? Mention some examples of the extreme divisibility of matter.

9. What is meant by the Indestructibility of matter? May it be changed in form and in external appearance? Give examples of such changes.

evaporated by the heat of the sun, or, in other words, when "it dries up," [illegible] slowly in the form of steam or vapor. This vapor [illegible] in the air and constitutes clouds: these [illegible] the earth in the shape of rain, snow, or hail, and [illegible] supply [illegible] fountains, rivers, etc. The water on or in the earth, therefore, is constantly changing its shape or situation, but no particle of it is ever actually destroyed.

9. The [illegible] of which fuel is composed are not destroyed when the fuel is burnt. Parts of them arise in smoke or vapor, and the remainder is reduced to ashes. A body in burning undergoes remarkable changes; but the various parts into which it has been separated by combustion, continue in existence, and retain all the essential properties of bodies.

10. Inertia is the resistance which inactive matter makes to a change of state, whether of motion or rest.

A body at rest cannot put itself in motion, nor can a body in motion stop itself.

A body, when put in motion, will continue to move forever, unless it be stopped. When a stone or ball is thrown from the hand, there are two forces which continually operate to stop it, namely, the resistance of the air, and gravitation: all motion which is caused by animal or mechanical power, will be destroyed by the combined action of these forces. But could these forces be suspended, the body in motion would continue to move forever.

Fig. 2.

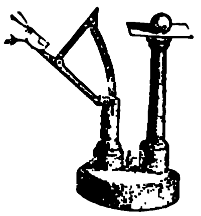


Fig. 2 represents the simple apparatus of Mr Wightman, for illustrating inertia. A ball and a card being placed upon the pillar, motion is given to the card by means of a spring, but the ball remains on the pillar.

11. Attraction is the tendency which different bodies or portions of matter have, to approach or to adhere to each other.

---

10. What is meant by Inertia? Can a body at rest put itself in motion? Can a body in motion stop itself? When a stone or ball is thrown from the hand, how many forces continually operate to stop it? What are they? How could a body in motion be made to move forever? Explain the apparatus for illustrating inertia.

Every portion of matter is attracted by every other portion of matter, and this attraction increases as the quantity of matter is increased, and diminishes as the quantity of matter is diminished.

12. There are two kinds of attraction belonging to all matter, namely, the attraction of gravitation and the attraction of cohesion.

The attraction of gravitation is the tendency of different bodies to approach each other.

The attraction of cohesion is that which causes the particles of a body to cohere to each other.

By the attraction of gravity, a stone falls to the ground. By the attraction of cohesion, the particles which compose the stone are held together.

1. All matter is composed of very minute particles, which are connected together in different bodies by different degrees of cohesion.*

2. The particles of which bodies are composed absolutely touch one another in few points only. There are small spaces called *pores*† between the particles; and the proportion of these pores gives rise to the terms density and rarity. A body in which the pores are small and few in number, is called a *dense* body. When the pores are large and numerous, the body is said to be *rare*.

Density, therefore, implies the closeness and compactness of the

---

* Cohesive attraction is illustrated by means of a pair of *leaden hemispheres*, which being pressed together, will be found to cohere. The experiment may be made with equal success with two bullets scraped smooth at the points of contact.

† The pores of bodies are generally filled with air.

---

11. What is attraction? Is every portion of matter attracted by every other portion of matter? How does this attraction increase and diminish?

12. How many kinds of attraction are there belonging to all matter? What is the attraction of gravitation, or gravity? What is the attraction of cohesion, or cohesive attraction? What causes a stone to fall to the ground? By what are the particles which compose the stone held together? Of what is matter composed? Is the cohesive power which unites them the same in all bodies? How may cohesive attraction be illustrated? Do the particles of matter in bodies absolutely touch each other? What are the spaces between them called?

particles of a body, and indicates the quantity of matter contained in it under a given bulk.

Rarity is the reverse of density, and implies extension of bulk, without increase of quantity of matter.

13. Compressibility implies the reduction of the limits of extension. Of this all substances are susceptible if a sufficient force be applied.*

14. Expansibility is the reverse of compressibility, and implies the increase of the limits of extension.

15. Mobility implies susceptibility of motion.

16. Elasticity is the property which causes a body to resume its shape after being compressed or expanded.

Thus, when a bow is bent, its elasticity causes it to resume its shape. India-rubber possesses this property in a remarkable degree, but the gases in a still greater. The elasticity of ivory is very perfect, that is to say, it restores itself after compression with a force very nearly equal to that exerted in compressing it. Liquids, on the contrary, have scarcely any elasticity.

17. Malleability implies susceptibility of extension under the hammer or the rolling-press. This property belongs to some of the metals, as gold, silver, iron, copper, &c., but not to all; and it is of vast importance to the arts and conveniences of life. Gold is the most malleable of all metals.

18. Brittleness is the reverse of malleability, and implies aptness to break into irregular fragments. This property belongs chiefly to hard bodies.

* Sir Isaac Newton conjectured, that if the earth were so compressed as to be absolutely without pores, its dimensions might not be more than a cubic inch.

What do you understand by density? What by rarity?

13. What is compressibility? Are all substances susceptible of it?

14. What is expansibility?

15. What is mobility?

16. What is elasticity? What substance possesses this property in a remarkable degree?

17. What is malleability? Does this property belong to all the metals? What metal possesses it in the highest degree?

18. What is brittleness? What bodies are most brittle?

19. Ductility is that property which renders a substance susceptible of being drawn into wire.

Platina is the most ductile of all metals. It can be drawn into wire scarcely larger than a spider's web.

20 Tenacity implies a great degree of adhesion among the particles of bodies. The tenacity of bodies constitutes their strength, or their capability of sustaining weight. Iron, on account of its fibrous structure,is very tenacious.

CHAPTER III.

OF GRAVITY.

21. The term Gravity, in Philosophy, expresses the reciprocal attraction of separate portions of matter.

All matter possesses this attraction, and all bodies attract each other with a force proportionate to their size and density, when at a given distance from each other.

A body unsupported falls to the earth. This is caused by the superior attraction of the earth, arising from its density and size.

22. The attraction of gravitation causes weight.

1. When we say that a body weighs an ounce, a pound, or a hundred pounds, we express, by these terms, the degree of attraction by which it is drawn towards the earth.

2. *Weight, therefore, is the measure of the earth's attraction.* As this attraction depends upon the quantity of matter there is in a body, it follows that those bodies which contain the most matter will be most strongly attracted, and will consequently be the heaviest.

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19. What is ductility? Which is the most ductile of the metals?

20. What is tenacity? Which is the most tenacious of the metals?

21. What do you understand by the term gravity? Do all bodies possess this attraction? To what is its force proportional? If a body be unsupported, will it remain stationary? Why will it fall?

22. What causes weight? When you say that a body weighs an ounce, what do you mean by it? What, therefore, is weight?

23. The force of gravity is greatest at the surface of the earth, and decreases both upwards and downwards, but in different degrees.*

It decreases above the surface as the square of the distance from the centre increases. From the surface to the centre it decreases simply as the distance increases. That is, gravity at the surface of the earth (which is about 4000 miles from the centre) is four times more powerful than it would be at double that distance, or 8000 miles from the centre.

According to the principles just stated, a body which at the surface of the earth weighs a pound, at the centre of the earth will weigh nothing.

1000 miles from the centre it will weigh $\frac{1}{4}$ of a pound,
2000 " " " " " " $\frac{2}{4}$ of a pound,
3000 " " " " " " $\frac{3}{4}$ of a pound,
4000 " " " " " " 1 pound,
8000 " " " " " " $\frac{1}{4}$.
12000 " " " " " " $\frac{1}{9}$, &c.†

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* The force of gravity is absolutely greatest at the centre of the earth; but at that point it is exerted in all directions, and consequently a body at that point would remain stationary, because there is no superior attraction for it to obey.

† It follows from what has been stated, with regard to weight as a consequence of attraction, that if there were but one body in the universe, it would have no weight, because there would be nothing to attract it. But cohesive attraction would still exist, and keep the particles which compose the body united. As the attraction between all bodies is mutual, it follows that when a stone or any heavy body falls to the earth, the earth will rise to meet it. But as the attraction is in proportion to the quantity of matter each contains, the stone will fall as much farther than the earth rises, as the earth exceeds the stone in mass. Now the earth is one quatrillion, that is, one thousand million millions times larger than the largest body which has ever been known to fall through our atmosphere. Supposing, then, that such a body should fall through a distance of 1000 feet—the earth would rise no more than the hundred billionth part of an inch, a distance altogether imperceptible to our senses. The principle of mutual attraction is not confined to the earth. It extends to the sun, the planets, comets, and stars. The earth attracts each of them, and each of them

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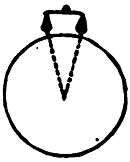
23. Where is the force of gravity greatest? How does it change? How does it decrease above the surface? How below?

24. The direction in which falling bodies approach the surface of the earth, is called a vertical line.* Such lines are everywhere perpendicular to the surface, and when prolonged will meet nearly at the centre of the earth.

Fig. 3.



For this reason no two lines suspended by weights, will be parallel to each other. Even a pair of scales, hanging perpendicular to the earth, are not exactly parallel, because they point to the same spot, namely, the centre of the earth; but the convergency is so small, that their inclination is not perceptible to our senses. [See Fig. 3.] For the same reason no two bodies can fall to the earth in parallel lines.

25. According to the laws of attraction, all bodies at an equal distance from the earth will fall to it in the same space of time, if nothing impede them. But bodies of different density fall with different degrees of velocity, on account of the resistance of the air; and as heavy bodies overcome this resistance more easily than light ones, the former will fall with the greater velocity.

The resistance which the air opposes to the fall of bodies, is proportioned to their surface, not to their weight.

attracts the earth, and these mutual attractions are so nicely balanced by the power of God, as to cause the regular motions of all the heavenly bodies, the diversity of the seasons, the succession of day and night, summer and winter, and all the grand operations which are described in astronomy.

* A vertical line is sometimes called a *plumb-line*, because it is formed by a weight suspended at rest from a string. As the weight thus employed is usually of *lead*, the term *plumb*, from the Latin *plumbum*, lead, is applied to the line.

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24. In what direction will a falling body approach the surface of the earth? Will the lines of suspension of different bodies ever be parallel? Where will they meet, if sufficiently produced?

25. Will all bodies at equal distances from the earth, fall to it in the same time? Why not? What bodies falls fastest? To what is the resistance of the air proportional?

Heavy bodies can be made to *float* in the air, instead of falling immediately to the ground, by making the extent of their surface counterbalance their weight. Thus gold, which is one of the heaviest of all substances, when spread out into thin leaf, is not attracted by gravity with sufficient force to overcome the resistance of the air; it therefore floats in the air, or falls slowly.

26. All substances are influenced by gravity, in exact proportion to their quantity of matter, and their distance from the central point of attraction.

1. Even air itself, light as it seems, is subject to this attraction. The air* probably extends to a height of more than forty five miles above the surface of the earth. The pressure of the upper parts of the atmosphere on those beneath, renders the air near the surface of the earth much more dense than that in the upper regions. This pressure is caused by the attraction of the earth, or, what is the same thing, the weight of the air above; and it would cause the air to fall like other bodies completely to the earth, were it not for the elasticity of that portion which is near the surface.

2. The air therefore, of which the atmosphere is composed, exists in a state of compression, which causes it to be heaviest near the surface of the earth.

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* We have no means of ascertaining the exact height to which the air extends. Sir John Herschel says, "Laying out of consideration all nice questions as to the probable existence of a definite limit to the atmosphere, beyond which there is absolutely and rigorously speaking *no* air, it is clear, that for all practical purposes we may speak of those regions which are more distant above the earth's surface than the hundredth part of its diameter as void of air, and of course, of clouds, (which are nothing but visible vapors, diffused and floating in the air, sustained by it, and rendering it turbid, as mud does water.) It seems probable, from many indications, that the greatest height at which visible clouds ever exist does not exceed ten miles; at which height the density of the air is about an eighth part of what it is at the level of the sea." Although the exact height to which the atmosphere extends has never been ascertained, it ceases to reflect the sun's rays at a greater height than forty-five miles.

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26. In what proportion are all substances influenced by gravity? Is air affected by it? How far does the air extend above the surface of the earth? What causes the air to be more dense at the surface of the earth? What causes this pressure? Why does not the air fall to the earth like other bodies? Where is the air heaviest? What effect have gravity and elasticity upon the air?

27. The specific gravity of bodies is a term used to express the relative weight of equal bulks of different bodies.*

1. If we take equal bulks of lead, wood, cork, and air, we find the lead to be the heaviest, then the wood, then the cork, and lastly the air. Hence we say that the specific gravity of cork is greater than that of air, the specific gravity of wood is greater than that of cork, and the specific gravity of lead greater than that of wood, &c.

2. From what has now been said with respect to the attraction of gravitation and the specific gravity of bodies, it appears that although the earth attracts all substances, yet this very attraction causes some bodies to rise and others to fall.

3. Those bodies or substances, the specific gravity of which is greater than that of air, will fall, and those whose specific gravity is less than that of air, will rise; or rather, the air being more strongly attracted will get beneath them, and thus displacing them, will cause them to rise. For the same reason, cork and other light substances will not sink in water, because the specific gravity of water being greater, the water is more strongly attracted, and will be drawn down beneath them. [For a table of the specific gravity of bodies, see Hydrostatics.]

4. The principle which causes balloons to rise, is the same which occasions the ascent of smoke, steam, &c. The materials of which a balloon is made, are heavier than air, but their extension is greatly increased, and they are filled with an elastic fluid of a different nature, specifically lighter than air, so that on the whole, the balloon when thus filled is much lighter than

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* The quantity of matter in a body is estimated, not by its apparent size, but by its weight. Some bodies, as cork, feathers, &c., are termed light; others, as lead, gold, mercury, &c., are called heavy. The reason of this is, that the particles which compose the former are not closely packed together, and therefore they occupy considerable space; while in the latter they are joined more closely together, and occupy but little room. A pound of cork and a pound of lead, therefore, will differ very much in apparent size, while they are both equally attracted by gravity, that is, they weigh the same.

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27 What is specific gravity? Illustrate this. Does the attraction of the earth cause all bodies to fall? What bodies will fall? What rise? How does the air cause them to rise? Why do not cork and other light bodies sink in water? Explain the principle upon which balloons rise.

a portion of air of the same size or dimensions, and it will consequently rise.

5. Gravity, therefore, causes bodies which are lighter than air to ascend, those which are of equal weight with air to remain stationary, and those which are heavier than air to descend; but the rapidity of their descent is affected by the resistance of the air; which resistance is proportioned to the extent of the surface of the falling body.

CHAPTER IV.

MECHANICS, OR THE LAWS OF MOTION.

28. Mechanics is that branch of Natural Philosophy which relates to motion and the moving powers, their nature and laws, with their effects in machines, &c.

29. Motion is a continued change of place.

On account of the inertia of matter, a body cannot put itself in motion, nor when it is in motion can it stop itself.

30. The power which puts a body into motion is called a *force*; and the power which has a tendency to stop or impede motion is called *resistance*.

31. The motion of a body impelled by a single force is always in a straight line, and in the same direction in which the force acts.

32. The rapidity with which a body moves is called its velocity.

What effect has gravity on bodies lighter than the air? What effect on bodies of equal weight? What effect on those that are heavier? What affects the rapidity of their descent? To what is the resistance of the air proportioned?

28. What is Mechanics?

29. What is motion? Why cannot a body put itself in motion? Why cannot a body stop itself when in motion?

30. What is force? What is resistance?

31. When is the motion of a body in a straight line? In what direction will it move?

32. What is meant by velocity?

33. The velocity of a given body is proportional to the force by which it is put in motion.*

34. The velocity of a moving body is determined by the time that it occupies in passing through a given space. The greater the space, and the shorter the time, the greater is the velocity.

Thus, if one body move at the rate of six miles, and another twelve miles in the same time, the velocity of the latter is double that of the former.†

35. The velocity of a body is measured by the space over which it moves, divided by the time which it employs in the motion.

Thus, if a body move one hundred miles in twenty hours, the velocity is one hundred divided by twenty, that is, five miles an hour.

* The mean velocity of rivers is about four feet in a second; of a very rapid stream, about 13 feet; of a moderate wind, about 14 feet; of a storm, 54 feet; of a violent hurricane, 135 feet; of sound, 1142 feet; of atmospheric air rushing into a vacuum, 1250 feet; of a musket-ball, 1280 feet; of a rifle-ball, 1600; of a cannon-ball of 24 pounds, 2400 feet; of a point at the surface of the earth, under the equator, 1500 feet; of the earth's centre in its orbit round the sun, 101,861 feet.

The average rate of steamers between New York and Albany, exclusive of stoppages, is ten and a half miles per hour; of the mail trains on the great railroads, about 25 miles an hour; of the fastest sailing vessel, 15 feet in a second; of the swiftest race-horse, 42 feet in a second.

† Velocity is sometimes called absolute, and sometimes relative. Velocity is called absolute when the motion of a body in space is considered without reference to that of other bodies. When, for instance, a horse goes a hundred miles in ten hours, his absolute velocity is ten miles an hour. Velocity is called relative when it is compared with that of another body. Thus, if one horse travel only fifty miles in ten hours, and another one hundred in the same time, the absolute velocity of the first horse is five miles an hour, and that of the latter is ten miles; but their relative velocity is five miles.

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33. To what is the velocity of a moving body proportional?

34. How is the velocity of a moving body determined? If one body go through six miles in an hour, and another twelve, how does the velocity of the latter compare with that of the former? What is meant by absolute velocity? Give an example. When is the velocity of a body termed relative? Give an example.

35. How is the velocity of a body measured? Illustrate this.

36. The time employed by a body in motion may be ascertained by dividing the space by the velocity.

Thus, if the space be one hundred miles, and the velocity five miles in an hour, the time will be one hundred divided by five, which is twenty hours.

37. The space also may be ascertained by multiplying the velocity by the time.

Thus, if the velocity be five miles an hour, and the time twenty hours, the space will be twenty multiplied by five, which is one hundred miles.

38. There are three terms applied to motion to express its kind; namely, uniform, accelerated, and retarded motion.

Uniform motion is that of a body passing over equal spaces in equal times.

Accelerated motion is that in which the velocity continually increases as the body moves.

Retarded motion is that in which the velocity decreases as the body moves.

39. Uniform motion is produced by a force having acted on a body, and then ceasing to act

A ball struck by a bat, or a stone thrown from the hand, is in theory an instance of uniform motion; and if both the attraction of gravity and the resistance of the air could be entirely removed, it would proceed onwards in a straight line, and with a uniform motion forever. But as the resistance of the air and gravity tend to deflect it, it in fact becomes an instance first of retarded and then of accelerated motion.

40. Accelerated motion is produced by the continued action of one or more forces.

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36. How do you ascertain the time employed by a body in motion? Illustrate this.

37 How can you ascertain the space? Illustrate this.

38 How many terms are applied to motion to express its kind? What are they? What is uniform motion? Accelerated? Retarded?

39. How is uniform motion produced? Why is not a ball struck by a bat, or a stone thrown from the hand, an instance of uniform motion? How can it be made an instance?

40. How is accelerated motion produced?

1. Thus, when a stone falls from a height, the impulse which it receives from gravity would be sufficient to bring it to the ground with a uniform velocity. But the stone while falling at this rate is still acted upon by gravity with an additional force, which continues to impel it during the whole time of its descent.

2. *In the first second it falls sixteen feet, three times that distance in the next, five times in the third, seven times in the fourth, and so on, regularly increasing its velocity according to the number of seconds consumed in falling.*

3. The height of a building, or the depth of a well, may thus be measured by observing the length of time which a stone takes in falling from the top to the bottom.*

41. Retarded motion is produced when a body in motion encounters a force operating in an opposite direction.

1. Thus, when a stone is thrown perpendicularly upwards, the force of gravity is continually operating in the opposite direction, and attracting it downwards to the earth. The stone moves upwards slower and slower, until the upward motion ceases, and the body returns with accelerated motion to the earth. It is found that a body thrown perpendicularly upwards, takes the same length of time in ascending that it takes in descending.

2. Perpetual motion has never yet been produced by art; and the principles of mechanics seem to prove that such a motion is impossible; for although in many cases of bodies acting upon one another, there is a gain of absolute motion, yet the gain is always equal in opposite directions, so that the

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* The spaces through which a body falls in equal successive portions of time, increase as the odd numbers 1, 3, 5, 7, &c.; that is, a falling body descends in the 2d second of its fall through 3 times, and in the 3d second through 5 times the space passed over in the first second. But the entire spaces through which a body will have fallen in any given number of seconds, increase as the squares of the times.

Give an instance of accelerated motion. How far does a stone fall the first second of time? The second? Third? Fourth? How can you measure the height of a building, or the depth of a well?

41. How is retarded motion produced? Give an example. How does the time of the ascent of a body thrown perpendicularly upwards, compare with that of its descent? Why cannot perpetual motion be produced?

quantity of direct motion is never increased. But nature abounds with examples of perpetual motion, as for instance, the motion of the heavenly bodies, described in the science of astronomy.

42. The momentum of a body is its quantity of motion, or the force with which it would strike against another body. It is measured by multiplying its weight by its velocity.*

Thus, if a body weighing six pounds move at the rate of two miles in a second of time, its momentum may be represented by six multiplied by two, which is twelve. Hence a small or a light body may be made to strike against another body with a greater force than a heavy one, simply by giving it sufficient velocity.

43. The *action* of a body is the effect which it produces upon other bodies. *Reaction* is the effect which it receives from the body on which it acts.

Thus, when a body in motion strikes against another body, it acts upon it, or produces action; but it also meets with resistance from the body which is struck, and this resistance is the reaction of the body.

44. Action and reaction are always equal, but in opposite directions.

1. Experiments to show the mutual action and reaction of bodies, are made with both elastic and non-elastic bodies. Fig. 4

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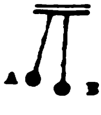
* The quantity of motion communicated to a body does not affect the duration of the motion. If but little motion be communicated, the body will move slowly. If a great degree be imparted, it will move rapidly. But in both cases the motion will continue until it is destroyed by some external force.

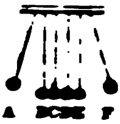
42. What is the momentum of a body? How can the momentum of a body be ascertained? Note. Does the quantity of motion communicated to a body affect the duration of the motion? If but little motion is communicated, how will the body move? If a great degree? How long will the motion continue? How can a light body be made to have a greater momentum than a heavy one? Give an instance of this.
43. What is meant by action? Reaction? Illustrate this.
44. How do action and reaction compare?

Fig. 4.



represents two ivory balls, A and B, of equal weight, &c., suspended by threads. If the ball A be drawn a little on one side and then let go, it will strike against the other ball B, and drive it off to a distance equal to that through which the first ball fell; but the motion of A will be stopped, because when it strikes B it receives in return a blow equal to that which it gave, but in a contrary direction, and its motion is thereby stopped, or rather, given to B. Therefore, when a body strikes against another, the quantity of motion communicated to the second body is lost by the first; but this loss proceeds, not from the blow given by the striking body, but from the reaction of the body which it struck.

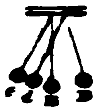
Fig. 5.



2. Fig. 5 represents six ivory balls, of equal weight, suspended by threads. If the ball A be drawn out of the perpendicular, and let fall against B, it will communicate its motion to B, and receive a reaction from it which will stop its own motion. But the ball B cannot move without moving C; it will therefore communicate the motion which it received from A to C, and receive from C a reaction which will stop its motion. In like manner the motion and reaction are received by each of the balls, D, E, F; but as there is no ball beyond F to act upon it, F will fly off.

N. B. This experiment can be accurately performed by those bodies only which are perfectly elastic.

Fig. 6.



3. Fig. 6 represents two balls of clay, (which are not elastic,) of equal weight, suspended by strings. If the ball D be raised and let fall against E, only part of the motion of D will be destroyed by it, (because the bodies are non-elastic,) and the two balls will move on together to *d* and *e*, which are less distant from the vertical line than the ball D was before it fell. Still, however, action and reaction are equal, for the action on E is only enough to make it move through a smaller space, but so much of D's motion is now also destroyed.*

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* Figs. 4 and 5, as has been explained, show the effect of action and reaction in elastic bodies, and Fig 6 shows the same effect in non-elastic

Explain Fig. 4. Fig. 5. Fig. 6.

4. It is upon the principle of action and reaction, that birds are enabled to fly. They strike the air with their wings, and the reaction of the air enables them to rise, fall, or remain stationary at will, by increasing or diminishing the force of the stroke of their wings.*

5. It is likewise upon the same principle of action and reaction, that fishes swim, or, rather, make their way through the water; namely, by striking the water with their fins.†

6. Boats are also propelled by oars on the same principle, and the oars are lifted out of the water, after every stroke, so as completely to prevent any reaction in a backward direction.

45. Motion may be caused either by action or reaction. When caused by action it is called incident, and when caused by reaction it is called reflected motion.‡

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bodies. When the elasticity of a body is imperfect, an intermediate effect will be produced; that is, the ball which is struck will rise higher than in case of non-elastic bodies, and less so than in that of perfectly elastic bodies; and the striking ball will be retarded more than in the former case, but not stopped completely, as in the latter. They will, therefore, both move onwards after the blow, but not together, or to the same distance; but in this, as in the preceding cases, the whole quantity of motion destroyed in the striking ball, will be equal to that produced in the ball struck. Connected with "the Boston school apparatus" is a stand with ivory balls, to give a visible illustration of the effects of collision.

* The muscular power of birds is much greater in proportion to their weight than that of man. If a man were furnished with wings sufficiently large to enable him to fly, he would not have sufficient strength, or muscular power, to put them in motion.

† The power possessed by fishes, of sinking or rising in the water, is greatly assisted by a peculiar apparatus furnished them by nature, called an air-bladder, by the expansion or contraction of which they rise or fall, on the principle of specific gravity.

‡ The word *incident* implies *falling upon*, or *directed towards*. The word *reflected* implies *turned back*. Incident motion is motion directed towards any particular object, against which a moving body strikes. Reflected motion is that which is caused by the reaction of the body which is struck. Thus, when a ball is thrown against a surface, it rebounds or

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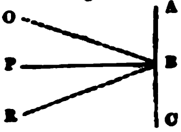
Upon what principle do birds fly? Explain how Upon what principle do fishes swim? Upon what principle do boats move upon the water? Explain how.

45. How may motion be caused? When caused by action what is it called? When caused by reaction what is it termed?

46. The angle* of incidence is the angle formed by the line which the incident body makes in its passage towards any object, with a line perpendicular to the surface of the object.

Thus, in Fig. 7, the line A B C represents a wall, and P B a line perpendicular to its surface. O is a ball moving in the direction of the dotted line, O B. The angle O B P is the angle of incidence.

Fig. 7.



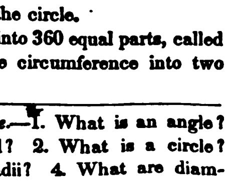
is turned back. This return of the ball is called reflected motion. As reflected motion is caused by reaction, and reaction is caused by elasticity, it follows, that reflected motion is always greatest in those bodies which are most elastic. For this reason, a ball filled with air rebounds better than one stuffed with bran or wool, because its elasticity is greater. For the same reason, balls made of caoutchouc, or India-rubber, will rebound more than those which are made of most other substances.

* As this book may fall into the hands of some who are unacquainted with geometrical figures, a few explanations are here subjoined.

1. An angle is the opening made by two lines which meet each other in a point. The size of the angle depends upon the opening, and not upon the length of the lines.

2. A circle is a perfectly round figure, every part of the outer edge of which, called the circumference, is equally distant from a point within, called the centre. (See Fig. 8.)

Fig. 8.



3. The straight lines drawn from the centre to the circumference are called radii. [The singular number of this word, is radius.] Thus, in Fig. 8, the lines CD, CO, CR, and CA, are radii.

4. The lines drawn through the centre, and terminating in both ends at the circumference, are called diameters. Thus, in the same figure, D A is a diameter of the circle.

5. The circumference of all circles is divided into 360 equal parts, called degrees. The diameter of a circle divides the circumference into two equal parts of 180 degrees each.

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46. What is the angle of incidence? (*Note.*—1. What is an angle? Upon what does the size of an angle depend? 2. What is a circle? 3. What are radii? What lines in Fig. 8 are radii? 4. What are diameters? In Fig. 8, what line is the diameter? 5. How is the circumference of all circles divided? Into how many parts does the diameter of a circle divide it?

47. The angle of reflection is the angle formed by the perpendicular with the line made by the reflected body as it leaves the surface against which it struck.

Thus, in Fig. 7, the angle P B R is the angle of reflection.

48. The angles of incidence and reflection are always equal to one another.

1. Thus, in Fig. 7, the angle of incidence, O B P, and the angle of reflection P B R, are equal to one another; that is, they contain an equal number of degrees.

6. All angles are measured by the number of degrees which they contain. Thus, in Fig. 8, the angle R C A, as it includes one quarter of the circle, is an angle of 90 degrees, which is a quarter of 360. And the angles R C O and O C D are angles of 45 degrees.

7. Angles of 90 degrees are right angles; angles of less than 90 degrees, acute angles, and angles of more than 90 degrees are called obtuse angles. Thus, in Fig. 8, R C A is a right angle, O C R acute, and O C A an obtuse angle.

8. A perpendicular line is a line which makes an angle of 90 degrees on each side of any other line or surface; therefore, it will incline neither to the one side nor to the other. Thus, in Fig. 8, R C is perpendicular to D A.

9. The tangent of a circle is a line which touches the circumference, without cutting it when lengthened at either end. Thus, in Fig. 8, the line R T is a tangent.

10. A square is a figure having four equal sides, and four equal angles. These will always be right angles. (See Fig. 9.)

11. A parallelogram is a figure whose opposite sides are equal and parallel. (See Figs. 10 and 11.) A square is also a parallelogram.

12. A rectangle is a parallelogram whose angles are right angles.

13. The diagonal of a square, of a parallelogram, or a rectangle, is a line drawn through either of them, and terminating at the opposite angles. Thus, in Figs. 9, 10, and 11, the line A C is the diagonal of the square, parallelogram, or rectangle.

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6. How are all angles measured? Illustrate this by Fig. 8. 7. How many degrees do right angles contain? Acute? Obtuse? Illustrate these angles by Fig. 8. 8. What is a perpendicular line? What line is perpendicular in Fig. 8? 9. What is a tangent? What line is a tangent in Fig. 8? 10. What is a square? 11. What is a parallelogram? 12. A rectangle? 13. What is a diagonal? What lines are diagonals in Figs. 9, 10, and 11?) Explain the angle of incidence by Fig. 7.

47. What is the angle of reflection? Illustrate this by Fig. 7.

48. How do the angles of incidence and reflection compare with each other? Illustrate this by Fig. 7

2. From what has now been stated with regard to the angles of incidence and reflection, it follows, that when a ball is thrown perpendicularly against an object which it cannot penetrate, it will return in the same direction; but if it be thrown obliquely, it will return obliquely on the opposite side of the perpendicular. The more obliquely the ball is thrown, the more obliquely it will rebound.*

COMPOUND MOTION.

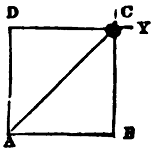
49. Compound motion is caused by the operation ot two or more forces at the same time.

50. When a body is struck by two equal forces in opposite directions, it will remain at rest.

51. A body struck by two forces in different directions, will move in a line between them. This line will be the diagonal of a parallelogram, having for its sides the lines through which the body would pass, if urged by each of the forces separately.

1. Let Fig. 9 represent a ball struck by the two equal forces, X and Y. In this figure, the forces are inclined to each other at an angle of 90 degrees, or a right angle. Suppose that the force X would send it from C to B, and the force Y, from C to D. As it cannot obey both, it will go between them to A, and the line C A, through which it passes, represents the diagonal of the square, A B C D.

Fig. 9.



The time occupied in its passage from C

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* It is from a knowledge of these facts that skill is acquired in many different sorts of games, as Billiards, Bagatelle, &c. A ball may also, on the same principle, be thrown from a gun against a fortification, so as to reach an object out of the range of a direct shot.

What follows from what has been stated with regard to the angles of incidence and reflection?

49. What is compound motion?

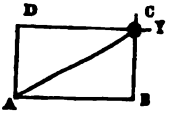
50. In what direction will a body, struck by two equal forces in opposite directions, move?

51. When struck by two forces inclined to each other, how will it move? What is this line called? Illustrate these, first, by Fig. 9, which represents a ball struck by two equal forces in different directions.

to A will be the same as the force X would require to send it to B, or the force Y to send it to D.

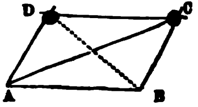
2. If the two forces acting on a body are unequal, but still operate at right angles to each other, the body will move from C to A as represented in Fig. 10; in which it is to be observed that the force Y is as much greater than the force X, as the length of the side C D of the rectangle A B C D, exceeds the length of the side C B.

Fig. 10.



3. When two forces operate in the direction of an acute angle, (see Fig. 11,) the body will move as represented by C A, in the parallelogram A B C D.

Fig. 11.



4. If the forces operate in the direction of an obtuse angle, the body will move as represented by D B in the same figure.

52. Circular motion is motion around a central point, and is caused by two forces operating at the same time, by one of which it is projected forward in a straight line, while by the other it is deflected towards a fixed point.

The whirling of a ball, fastened to a string held by the hand, is an instance of circular motion. The ball is urged by two forces, of which one is the force of projection, and the other the string which confines it to the hand. The two forces act at right angles to each other, and (according to No. 51) the ball will move in the diagonal of a parallelogram. But, as the force which confines it to the hand only keeps it within a certain distance, without drawing it nearer to the hand, the motion of the ball will be through the diagonals of an indefinite number of minute parallelograms, formed by every part of the circumference of the circle.

53. There are three different centres which require to be distinctly noticed; namely, the centre of magnitude, the centre of gravity, and the centre of motion.

Second, by Fig. 10, which represents a ball struck by two unequal forces, acting at right angles. Third, by Fig. 11, where the forces operate in the direction of an acute angle. Fourth, by Fig. 11, where the forces operate in the direction of an obtuse angle.

52. What is circular motion? How is it caused? Illustrate this.

53. How many different centres are there which require to be noticed? Define each of them.

The centre of magnitude is the central point of the bulk of a body.

The centre of gravity is the point about which all the parts balance each other.

The centre of motion is the point around which all the parts of a body move.

When the body is not of a size nor shape to allow every point to revolve in the same plane, the line around which it revolves is called the axis of motion.*

54. The centre or the axis of motion is generally supposed to be at rest.

Thus the axis of a spinning top is stationary, while every other part is in motion around it. The axis of motion and the centre of motion are terms which relate only to circular motion.

55. The two forces by which circular motion is produced, are called *central* forces. Their names are the centripetal force and the centrifugal force.†

56. The centripetal force is that which confines a body to the centre around which it revolves.

The centrifugal force is that which impels the body to fly off from the centre.

57. If the centrifugal force of a revolving body be destroyed, the body will immediately approach the centre which attracts it; but if the centripetal force be

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* Circles may have a centre of motion; spheres or globes have an axis of motion. Bodies that have only length and breadth may revolve around their own centre, or around axes; those that have the three dimensions of length, breadth, and thickness, must revolve around axes.

† The word *centripetal* means seeking the centre, and *centrifugal* means flying from the centre. In circular motion, these two forces constantly balance each other; otherwise the revolving body will either approach the centre or recede from it, according as the centripetal or centrifugal force is the stronger.

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54. Is the centre or axis of motion supposed to be at rest, or does it move? To what do the terms centre of motion and axis of motion relate?

55. What are the two forces called which produce circular motion? What is the name of each? What do the words centripetal and centrifugal mean?

56. Define a centripetal force. Also a centrifugal force.

57. If the centrifugal force be destroyed, to what point will the body tend?

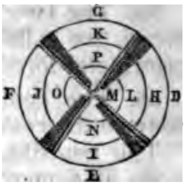
destroyed, the body will fly off in the direction of a tangent to the curve which it describes in its motion.

Thus, when a mop filled with water is turned swiftly round by the handle, the threads which compose the head will fly off from the centre; but being confined to it at one end, they cannot part from it; while the water they contain, being unconfined, is thrown off in straight lines.

58. The parts of a body which are farthest from the centre of motion, move with the greatest velocity; and the velocity of all the parts diminishes, as their distance from the axis of motion diminishes.

Fig. 12 represents the vanes of a windmill. The circles denote the paths in which the different parts of the vanes move. M is the centre or axis of motion around which all the parts revolve. The outer part revolves in the circle D E F G, another part revolves in the circle H I J K, and the inner part in the circle L N O P. Consequently, as they all revolve around M in the same time, the velocity of the parts which revolve in the outer circle is as much greater than the velocity of the parts which revolve in the inner circle, L N O P, as the diameter of the outer circle is greater than the diameter of the inner.

Fig. 12.



59. As the earth revolves round its axis, it follows, from the preceding illustration, that the portions of the earth which move most rapidly are nearest to the equator, and that the nearer any portion of the earth is to the poles, the slower will be its motion.

60. Curvilinear motion requires the action of two forces; for, the impulse of one single force always produces motion in a straight line.

What would be its direction if the centripetal force were destroyed? Give an example.

58. What parts of a body move with the greatest velocity? In what proportion does the velocity of all the parts diminish? What does Fig. 12 represent?

59. What follows, with regard to the motion of the earth, from the illustration of Fig. 12?

60. Of what is curvilinear motion always the result? Why?

61. A ball thrown in a horizontal direction is influenced by three forces; namely, first, the force of projection, (which gives it a horizontal direction;) second, the resistance of the air through which it passes, which diminishes its velocity, without changing its direction; and third, the force of gravity, which finally brings it to the ground.

62. The force of gravity is neither increased nor diminished by the force of projection.*

Fig. 13.

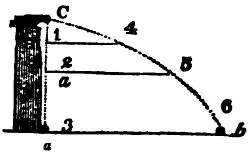


Fig. 13 represents a cannon, loaded with a ball, and placed on the top of a tower, at such a height as to require just three seconds for another ball to descend perpendicularly. Now suppose the cannon to be fired in a horizontal direction, and at the same instant the other ball to be dropped towards the ground. They will both reach the horizontal line at the base of the tower at the same instant. In this figure C *a* represents the perpendicular line of the falling ball. C *b* is the curvilinear path of the projected ball, 3 the horizontal line at the base of the tower. During the first second of time, the falling ball reaches 1, the next second 2, and at the end

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* The action of gravity being always the same, the shape of the curve of every projectile (see No. 63) depends on the velocity of its motion; but, whatever this velocity be, the moving body, if thrown horizontally from the same elevation, will reach the ground at the same instant. Thus, a ball from a cannon, with a charge sufficient to throw it half a mile, will reach the ground at the same instant of time that it would had the charge been sufficient to throw it one, two, or six miles, from the same elevation. The distance to which a ball will be projected, will depend entirely on the force with which it is thrown, or on the velocity of its motion. If it moves slowly, the distance will be short—if more rapidly, the space passed over in the same time will be greater; but in both cases the descent of the ball towards the earth, in the same time, will be the same number of feet, whether it moves fast or slow, or even whether it move forward at all, or not.

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61. How many forces act upon a ball thrown in a horizontal direction? What are they? Why do bodies fall to the ground?

62. Does the force of gravity either increase or decrease the force of projection? Give an illustration

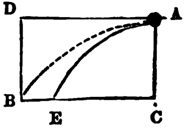
of the third second it strikes the ground. Meantime, that projected from the cannon, moves forward with such velocity, as to reach 4 at the same time that the falling ball reaches 1. But the projected ball falls downward exactly as fast as the other, since it meets the line 1 4, which is parallel to the horizon, at the same instant. During the next second the ball from the cannon reaches 5, while the other falls to 2, both having an equal descent. During the third second the projected ball will have spent nearly its whole force, and therefore its downward motion will be greater while the motion forward will be less than before. *Hence it appears that the horizontal motion does not interfere with the action of gravity, but that a projectile descends with the same rapidity while moving forward that it would if it were acted on by gravity alone.* This is the necessary result of the action of two forces.

63. A projectile is a body thrown into the air, as a rocket, a ball from a gun, or a stone from the hand.

The force of gravity and the resistance of the air cause projectiles to form a curve both in their ascent and descent; and in descending, their motion is gradually changed from an oblique towards a perpendicular direction.

In Fig. 14 the force of projection would carry a ball from A to D, while gravity would bring it to C. If these two forces alone prevailed, the ball would proceed in the dotted line to B. But as the resistance of the air operates in direct opposition to the force of projection, instead of reaching the ground at B, the ball will fall somewhere about E.*

Fig. 14



64. When a body is thrown in a horizontal direction, or upwards or downwards *obliquely*, its course will

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* It is calculated that the resistance of the air to a cannon-ball of two pounds weight, with the velocity of two thousand feet in a second, is more than equivalent to sixty times the weight of the ball.

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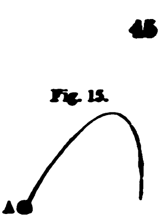
63. What is a projectile? What lines do projectiles describe? From what cause? Give the illustration. How great is the resistance of the air calculated to be to a cannon-ball of two pounds weight, with the velocity of 2000 feet in a second?

Fig. 15.



be in the direction of a curve-line, called a *parabola*;[*] (see Fig. 15,) but when it is thrown *perpendicularly* upwards or downwards, it will move perpendicularly, because the force of projection and that of gravity are in the same line of direction.

[*] The science of *gunnery* is founded upon the laws relating to projectiles. The force of gunpowder is accurately ascertained, and calculations are predicated upon these principles, which enable the engineer to direct his guns in such a manner as to cause the fall of the shot or shells in the very spot where he intends. The knowledge of this science saves an immense expenditure of ammunition, which would otherwise be idly wasted without producing any effect. In attacks upon towns and fortifications, the skilful engineer knows the means he has in his power, and can calculate, with great precision, their effects. It is in this way that the art of war has been elevated into a science, and much is made to depend upon skill, which, previous to the knowledge of these principles, depended entirely upon physical power.

The force with which balls are thrown by gunpowder is measured by an instrument called the *Ballistic pendulum.* It consists of a large block of wood suspended by a rod in the manner of a pendulum. Into this block the balls are fired, and to it they communicate their own motion. Now the weight of the block and that of the ball being known, and the motion or velocity of the block being determined by machinery, or by observation, the elements are obtained by which the velocity of the ball may be found; for, *the weight of the ball is to the weight of the block as the velocity of the block is to the velocity of the ball.* By this simple apparatus, many facts relative to the art of gunnery may be ascertained. If the ball be fired from the same gun, at different distances, it will be seen how much resistance the atmosphere opposes to its force at such distances. Rifles and guns of smooth bores may be tested, as well as the various charges of powder best adapted to different distances and different guns. These, and a great variety of other experiments, useful to the practical gunner or sportsman, may be made by this simple means.

The velocity of balls impelled by gunpowder from a musket with a common charge, has been estimated at about 1650 feet in a second of time, when first discharged. The utmost velocity that can be given to a cannon-ball, is 2000 feet per second; and this only at the moment of its leaving the gun.

In order to increase the velocity from 1650 to 2000 feet, one half more

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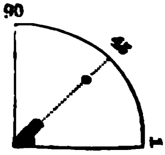
64. When a body is thrown horizontally, or upwards or downwards obliquely, in what curve will it move? In what line will it move when thrown upwards or downwards obliquely?

65. The random of a projectile is the horizontal distance from the place whence it is thrown, to the place where it strikes. The greatest random takes place at an angle of 45 degrees—that is, when a gun is pointed at this angle with the horizon, the ball is thrown to the greatest distance.

Fig. 16.



Let Fig. 16 represent a gun or a carronade, from which a ball is thrown at an angle of 45 degrees with the horizon. If the ball be thrown at any angle above 45 degrees, the random will be the same as it would be at the same number of degrees below 45 degrees.*

66. When the centre of gravity of a body is supported, the body itself will be supported; but when the centre of gravity is unsupported, the body will fall.†

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powder is required, and even then, at a long shot, no advantage is gained; since, at the distance of 500 yards, the greatest velocity that can be obtained is only 1200 or 1300 feet per second. Great charges of powder are therefore not only useless, but dangerous, for, though they give little additional force to the ball, they hazard the lives of many by their liability to burst.

Experiment has also shown, that, although long guns give a greater velocity to the shot than short ones, still, that on the whole, short ones are preferable; and, accordingly, armed ships are now almost invariably furnished with short guns, called carronades.

The length of sporting guns has also been greatly reduced, of late years. Formerly, the barrels were from four to six feet in length; but the best fowling-pieces of the present day have barrels of two feet, or two and a half, only, in length. Guns of about this length are now universally employed for such game as woodcocks, partridges, grouse, and such birds as are taken on the wing, with the exceptions of ducks and wild geese, which require longer and heavier guns.

* A knowledge of this fact, and calculations predicated on it, enables the engineer so to direct his guns, as to reach the object of attack when within the range of shot.

† The Boston School Apparatus contains a set of eight illustrations for

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65. What is the random of a projectile? At what angle does the greatest random take place?

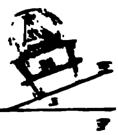
66. When the centre of gravity of a body is supported, will the body stand or fall? What if the centre be unsupported?

A line drawn from the centre of gravity, perpendicular to the horizon, is called the line of direction.*

67. When the line of direction falls within the base† of any body, the body will stand; but when that line falls *outside* **of the base, the body will fall or be overset.**

1. Fig. 18 represents a loaded wagon on the declivity of a hill. The line C F represents a horizontal line, D E the base of the wagon. If the wagon be loaded in such a manner that the centre of gravity be at B, the perpendicular B D will fall within the base, and the wagon will stand. But if the load be altered so that the centre of gravity be raised to A, the perpendicular A C will fall outside of the base, and the wagon will be overset. From this it follows that a wagon, or any carriage, will be most firmly supported when the line of direction of the centre of gravity falls exactly between the wheels; and that is the case on a level road. The centre of gravity in the human body, is between the hips, and the base is the feet.

Fig. 18.



So long as we stand upright, the line of direction falls within this base. When we lean to one side, the centre of gravity not being supported, we no longer stand firmly.

2. A rope-dancer performs all his feats of agility by dexterously supporting the centre of gravity. For this purpose he carries a heavy pole in his hands, which he shifts from side to side as he alters his position, in order to throw the weight to the side which is deficient; and thus, by changing the

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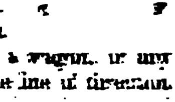
the purpose of giving a clear idea of the centre of gravity, and showing the difference between the centre of gravity and the centre of magnitude.

* The line of direction is the line which the centre of gravity would describe if the body were permitted to fall.

† The base of a body is its lowest side. The base of a body standing on wheels or legs, is represented by lines drawn from the lowest part of one wheel or leg, to the lowest part of the other wheel or leg.

Thus, in Figs. 17 and 18, D E represents the base of the wagon and of the table.

Fig. 17.



What is the line of direction?

67. If the line of direction falls within the base, will the body stand or fall? Give an illustration.

situation of the centre of gravity, he keeps the line of direction within the base, and he will not fall.*

A spherical body will roll down a slope, because the centre of gravity is not supported.†

68. When a body is of uniform density, the centre of gravity is in the same point with the centre of magnitude.

When one part of the body is composed of heavier materials than another part, the centre of gravity (being the centre of the weight of the body) no longer corresponds with the centre of magnitude. Thus, the centre of gravity of a cylinder plugged with lead, is not in the same point as the centre of magnitude.

Bodies, therefore, consisting of but one kind of substance, as wood, stone, or lead, and whose densities are consequently uniform, will stand more firmly than bodies composed of a variety of substances, of different densities.

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* The shepherds in the south of France afford an interesting instance of the application of the art of balancing to the common business of life. These men walk on stilts from three to four feet high, and their children, when quite young, are taught to practise the same art. By means of these odd additions to the length of the leg, their feet are kept out of the water, or the heated sand, and they are also enabled to see their sheep at a greater distance. They use these stilts with great skill and care, and run, jump, and even dance on them with great ease.

† A cylinder can be made to roll up a slope, by plugging one side of it with lead; the body being no longer of a uniform density, the centre of gravity is removed from the middle of the body to some point in the lead, as that substance is much heavier than wood. Now, in order that the cylinder may roll down the plane, as it is here situated, the centre of gravity must rise, which is impossible; the centre of gravity must always descend in moving, and will descend by the nearest and readiest means, which will be by forcing the cylinder up the slope, until the centre of gravity is supported, and then it stops.

A body also in the shape of two cones united at their bases, can be made to roll up an inclined plane formed by two bars with their lower ends inclined towards each other. This is illustrated by a simple contrivance in the "Boston School Set," and the fact illustrated is called "*the mechanical paradox.*"

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68. If a body is of uniform density, what centres will coincide? Give an example in which the centres of magnitude and gravity will not coincide

69. Bodies that have a narrow base are easily overset; for if they are in the least degree inclined, the line of direction will fall outside of the base, and their centre of gravity will not be supported.*

The broader the base, and the nearer the centre of gravity to the ground, the stronger will be the edifice.

For this reason a pyramid,† having a broad base and but little elevation, is the firmest of all structures.

70. When two bodies are fastened together, they are to be considered as forming but one body, and have but one centre of gravity. If the two bodies be of equal weight, the centre of gravity will be in the middle of the line which unites them. But if one be heavier than the other, the centre of gravity will be as much nearer to the heavier one as the heavier exceeds the light one in weight.

Fig. 19.

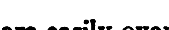
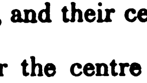


Fig. 20.



1. Fig. 19 represents a bar with an equal weight fastened at each end: the centre of gravity is at A, the middle of the bar, and whatever supports this centre will support both the bodies and the pole.
2. Fig. 20 represents a bar with an unequal weight at each end. The centre of gravity is at C nearer to the larger body.

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* A person can carry two pails of water more easily than one, because the pails balance each other, and the centre of gravity remains supported by the feet. But a single pail throws the centre of gravity on one side, and renders it more difficult to support the body.

† A cone has also the same degree of stability; but, strictly speaking, a cone is a pyramid with an infinite number of sides.

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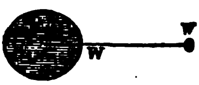
69. What shaped bodies are easily overturned? What bodies must stand more firmly than others? Why? Why do bodies which have a narrow base overturn more easily than those which have broad bases? Why can a person carry two pails of water more easily than one? Why is a pyramid the firmest of all structures?

70. If two bodies of equal weight are fastened together, where is the centre of gravity? If one be heavier than the other? What does Fig 19 represent? Fig. 20? Fig. 21?

3. Fig. 21 represents a bar with unequal weights at each end, but the larger weight exceeds the less in such a degree that the centre of gravity is within the larger body at C.

Fig. 21.

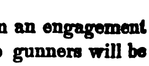


RESULTANT MOTION.

71. Resultant motion is the effect or result of two motions compounded into one.

If two men be sailing in separate boats, in the same direction, and at the same rate, and one toss an apple to the other, the apple would appear to pass directly across from one to the other, in a line of direction perpendicular to the side of each boat. But its real course is through the air in the diagonal of a parallelogram, formed by the lines representing the course of each boat, and perpendiculars drawn to those lines from the spot where each man stands as the one tosses and the other catches the apple. In Fig. 22 the lines A B and C D represent the course of each boat; E the spot where the man stands who tosses the apple; while the apple is in its passage, the boats have passed from E and G, to H and F respectively. But the apple having a motion, with the man, that would carry it from E to H and likewise a projectile force which would carry it from E to G, cannot obey them both, but will pass through the dotted line E F, which is the diagonal of the parallelogram E G F H.*

Fig. 22.



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* On the principle of resultant motion, if two ships in an engagement be sailing before the wind, at equal rates, the aim of the gunners will be exactly as though they both stood still. But if the gunner fire from a ship standing still, at another under sail, or a sportsman fire at a bird on the wing, each should take his aim a little forward of the mark, because the ship and the bird will pass a little forward while the shot is passing to them.

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71. What is resultant motion? Give the examples of this kind of motion.

THE PENDULUM.

72. The Pendulum* consists of a weight or ball suspended by a rod, and made to swing backwards and forwards.

73. The motions of a pendulum are called its vibrations, and they are caused by gravity.† The part of a circle through which it moves, is called its *arc*.

74. The vibrations of pendulums of equal length, are

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* The pendulum was invented by Galileo, a great astronomer of Florence, in the beginning of the seventeenth century. Perceiving that the chandeliers suspended from the ceiling of a lofty church vibrated long and with great uniformity, as they were moved by the wind or by any accidental disturbance, he was led to inquire into the cause of their motion, and this inquiry led to the invention of the pendulum. From a like apparently insignificant circumstance arose the great discovery of the principle of gravitation. During the prevalence of the plague, in the year 1665, Sir Isaac Newton retired into the country to avoid the contagion. Sitting in his orchard, one day, he observed an apple fall from a tree. His inquisitive mind was immediately led to consider the cause which brought the apple to the ground, and the result of his inquiry was the discovery of that grand principle of gravitation, which may be considered as the first and most important law of material nature. Thus, out of what had been before the eyes of men, in one shape or another, from the creation of the world, did these philosophers bring the most important results.

† When a pendulum is raised from its perpendicular position, its weight will cause it to fall, and, in the act of falling, it acquires a degree of motion which impels it to a height beyond the perpendicular almost as great as that to which it was raised. Its motion being thus spent, gravity again acts upon it to bring it to its original perpendicular position, and it again acquires an impetus in falling which carries it nearly as high on the opposite side. It thus continues to swing backwards and forwards, until the resistance of the air wholly arrests its motion. In the construction of clocks, an apparatus connected with the weight or the spring is made to act on the pendulum with such a force, as to enable it to overcome the resistance of the air, and keep up a continued motion.

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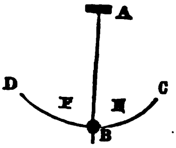
72 Of what does a pendulum consist? By whom was the pendulum invented? What led him to the discovery? By whom was the principle of gravitation discovered? What led him to the discovery?

73 What are the movements of the pendulum called? What is meant by its arc? What causes its vibrations?

very nearly equal, whether they move through a greater or less part of their arcs.

In Fig. 23, A B represents a pendulum. D F E C the arc in which it vibrates. If the pendulum be raised to E it will return to F, if it be raised to C it will return to D in nearly the same length of time, because that in proportion as the *arc* is more extended, the steeper will be its beginnings and endings, and, therefore, the more rapidly will it fall.

Fig. 23.



75. The time occupied in the vibration of a pendulum, depends upon its length. The longer the pendulum, the slower are its vibrations.

76. The length of a pendulum which vibrates sixty times in a minute (or, in other words, which vibrates seconds) is about 39 inches. But in different parts of the earth this length must be varied. A pendulum to vibrate seconds at the equator must be shorter than one which vibrates seconds at the poles.*

77. A clock is regulated by lengthening or shortening the pendulum. By lengthening the pendulum, the clock is made to go slower; by shortening it, it will go faster.†

* The equatorial diameter of the earth exceeds the polar diameter by about 34 miles; consequently, the poles must be nearer to the centre of the earth's attraction than the equator, and gravity must also operate with greater force at the poles than at the equator. Hence, also, the length of a pendulum, to vibrate in any given time, must vary with the latitude of the place.

† The pendulum of a clock is made longer or shorter, by means of a

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74. How do the vibrations of pendulums of equal length compare? Illustrate by Fig. 23.

75. Upon what does the time of the vibrations of a pendulum depend?

76. What is the length of a pendulum which vibrates sixty times in a minute? Do different situations affect the vibrations? How can a pendulum which vibrates seconds at the equator be made to vibrate seconds at the poles?

77. How is a clock regulated? What effect has the lengthening of the pendulum? The shortening? What is a clock? Of what use is the weight? What do the wheels show? Why do clocks go slower in summer than in winter? How does a watch differ from a clock?

THE MECHANICAL POWERS.

78. The Mechanical Powers are certain contrivances designed to increase or to diminish force, or to alter its direction.

There are five things in mechanics which require a distinct consideration, namely:

First, the power that acts.

Secondly, the resistance which is to be overcome by the power.

Thirdly, the centre of motion, or, as it is sometimes called, the fulcrum.*

Fourthly, the respective velocities of the power and the resistance; and,

Fifthly, the instruments employed in the construction of the machine.

1. The power that acts is the muscular strength of men, or

screw beneath the weight or ball of the pendulum. The clock itself is nothing more than a pendulum connected with wheel-work, so as to record the number of vibrations. A weight is attached, in order to counteract the retarding effect of friction, and the resistance of the air. The wheels show how many swings or beats of the pendulum have taken place in a given time, because, at every beat, the tooth of a wheel is allowed to pass. Now if this wheel have sixty teeth, it will turn round once in sixty vibrations of the pendulum, or in sixty seconds; and a hand, fixed on the axis of the wheel projecting through the dial-plate, will be the second-hand of the clock. Other wheels are so connected with the first, and the number of teeth in them is so proportioned, that the second-wheel turns sixty times slower than the first, and to this is attached the minute-hand; and the third wheel, moving twelve times slower than the second, carries the hour-hand. On account of the expansion of the pendulum by heat, and its contraction by cold, clocks will go slower in summer than in winter, because the pendulum is thereby lengthened at that season.

A watch differs from a clock, in having a vibrating wheel instead of a pendulum. This wheel is moved by a spring, called the *hair-spring*. The place of the weight is supplied by another larger spring, called the *main-spring*.

* The word fulcrum means a prop, or support.

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78. What are the mechanical powers? How many things are to be considered in order to understand the power of a machine? What is the first? Second? Third? Fourth? Fifth?

animals, the weight and momentum of solid bodies, the elastic force of steam, springs, the pressure of the air, &c.

2. The resistance to be overcome is the attraction of gravity, or of cohesion, the inertness of matter, &c.

3. The centre of motion, or the fulcrum, is the point about which all the parts of the body move.

4. The velocity is the rapidity with which an effect is produced.

5. The instruments are the mechanical powers which enter into the construction of the machine.*

79. There are six mechanical powers, namely, the Lever, the Pulley, the Wheel and Axle, the Inclined Plane, the Wedge, and the Screw.

80. The Lever† is an inflexible bar, moveable on a fulcrum, or prop.

There are three kinds of levers, called the first, second, and third kinds, according to the respective position of the fulcrum, the power, and the weight.

81. In a lever of the first kind, the weight is at one end, the power at the other, and the fulcrum between them.

Fig. 24 represents a lever of the first kind, resting on the fulcrum F, and moveable upon it. W is the weight to be moved, and P is the power which moves it. *The advantage gained in raising a weight by the use of this kind of lever, is in proportion as the distance of the power from the fulcrum exceeds that of the weight from the fulcrum.* Thus, in this figure, if the distance between P and F be double that be-

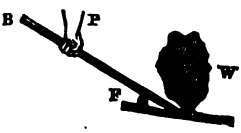
Fig. 24.

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* All machines and instruments are constructed on the principle of some one or more of the mechanical powers.

† The lever is made in a great variety of forms, and of many different

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What is the power that acts? What is the resistance to be overcome? What is the fulcrum? What is the velocity?

79. How many mechanical powers are there? What are they?

80. What is a lever? How many kinds of levers are there? How do they differ?

81. What is a lever of the first kind? What figure illustrates this? Explain it by the figure. To what is the advantage gained by this lever proportional?

tween W and F, then a man, by the exertion of a force of 100 pounds with the lever, can move a weight of 200 pounds. From this it follows that *the nearer the power is applied to the end of the lever, the greater is the advantage gained.* Thus, a greater weight can be moved by the same power, when applied at B, than when it is exerted at P.[*]

2. The common steelyard, an instrument for weighing articles, is constructed on the principle of the lever of the first kind. It consists of a rod or bar, marked with notches to designate the pounds and ounces, and a weight which is moveable along the notches. The bar is furnished with three hooks,

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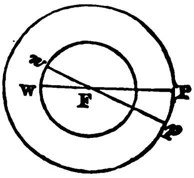
materials; and is much used in almost every kind of mechanical operation. Sometimes it is detached from the fulcrum, but most generally the fulcrum is a pin or rivet by which the lever is permanently connected with the framework of other parts of the machinery.

[*] *It is a fundamental principle in mechanics, that what is gained in power is lost in time.* To illustrate this principle, (Fig. 25,) W represents the weight, F the fulcrum, P the power, and the bar W F P the lever. To raise the weight W to *w*, the power P must descend to *p*. But as the radius of the circle in which the power P moves is double that of the radius of the circle in which the weight W moves, the arc P*p* is double the arc W*w*; or, in other words, the distance P*p* is double the distance of W*w*. Now, as these distances are traversed in the same time by the power and the weight respectively, it follows, that the velocity of the power must be double the velocity of the weight; that is, the power must move at the rate of two feet in a second, in order to move the weight one foot in the same time.

Fig. 25.



This principle applies not only to the lever, but to all the mechanical powers, and to all machines constructed on mechanical principles.

When two weights are equal, and the fulcrum is placed exactly in the centre of the lever between them, they will mutually balance each other; or, in other words, the centre of gravity being supported, neither of the weights will sink. This is the principle of the common scale for weighing.

To gain power by the use of the lever, the fulcrum must be placed near the weight to be moved, and the power at the greater distance from it. *The force of the lever, therefore, depends on its length, together with the power applied, and the distance of the weight from the fulcrum.*

What follows from this? What is meant by an inflexible bar? *Note.* What is a fundamental principle in Mechanics? Illustrate this by the figure. Does this principle apply to all the mechanical powers?

on the longest of which, the article to be weighed is always to be hung. The other two hooks serve for the handle of the instrument when in use. The pivot of each of these two hooks serves for the fulcrum. When suspended by the hook C, as in Fig. 26, it is manifest that a pound weight at E will balance as many pounds at W, as the distance between the pivot of D, and the pivot of C, is contained in the space between the pivot of C and the ring from which E is suspended.

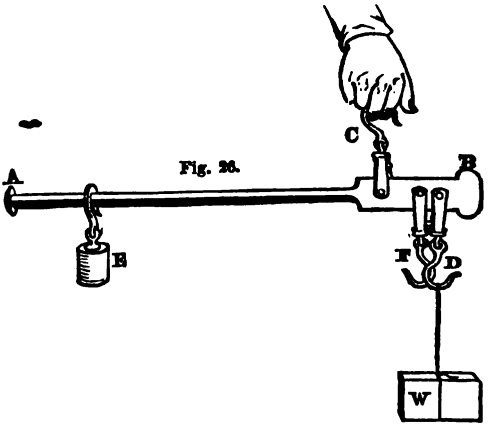


Fig. 26.

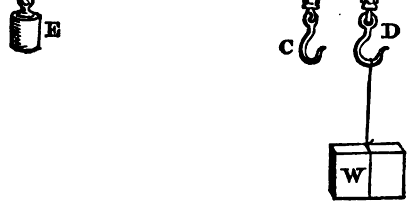
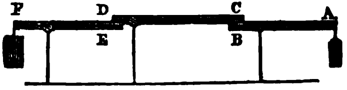


Fig. 27.

3. The same instrument may be used to weigh heavy articles, by using the middle hook for a handle, where, as will be seen in the figure, the space between the pivot of F (which in this case is the fulcrum) and the pivot of D (from which the weight is suspended) being lessened, is contained a greater number of times in the distance between the fulcrum and the notches on the bar. The steelyard is furnished with two sets of notches on opposite sides of the bar. An equilibrium will always be produced when the product of the weights on the opposite sides of the fulcrum into their respective distances from it, are equal to one another.

4. A balance, or pair of scales, is a lever of the first kind, with equal arms. Steelyards, scissors, pincers, snuffers, and a poker used for stirring the fire, are all levers of the first kind. The longer the handles of scissors, pincers, &c., and the shorter the points, the more easily are they used. A compound lever, represented in Fig. 28, consists of several levers, so arranged that the shorter arm of one may act on the longer arm of the other. Great power is obtained in this way; but its exercise is limited to a very small space.

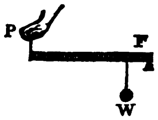
Fig. 28.



82. In a lever of the second kind, the fulcrum is at one end, the power at the other, and the weight between them.

1. Let Fig. 29 represent a lever of the second kind. F is the fulcrum, P the power, and W the weight. The advantage gained by a lever of this kind is in proportion as the distance of the power from the fulcrum exceeds that of the weight from the fulcrum. Thus in this figure, if the distance from P to F, is four times the distance from W to F, then a power of one pound at P will balance a weight of four pounds at W.

Fig. 29



2. On the principle of this kind of lever, two persons carry-

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Explain the common steelyard in Fig. 26. Also in Fig. 27. What is a balance, or pair of scales? Give some examples of levers of the first kind.

82. What is a lever of the second kind? What figure illustrates this? To what is the advantage gained by this lever proportional? Give some examples of levers of the second kind.

ing a heavy burden, suspended on a bar, may be made to bear unequal portions of it, by placing it nearer to the one than the other.

3. Two horses, also, may be made to draw unequal portions of a load, by dividing the bar attached to the carriage in such a manner that the weaker horse may draw upon the longer end of it.

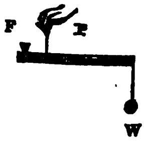
4. Oars, rudders of ships, doors turning on hinges, and cutting-knives, which are fixed at one end, are constructed upon the principle of levers of the second kind.*

83. In a lever of the third kind, the fulcrum is at one end, the weight at the other, and the power is applied between them.

1. In levers of this kind *the power must always exceed the weight, in the same proportion as the distance of the weight from the fulcrum exceeds that of the power from the fulcrum.*

2. In Fig. 30, F is the fulcrum, W the weight, and P the power between the fulcrum and the weight; and the power must exceed the weight in the same proportion that the distance between W and F exceeds the distance between P and F.

Fig. 30.



3. A ladder which is to be raised by the strength of a man's arms, represents a lever of this kind, where the fulcrum is that end which is fixed against the wall: the weight may be considered as at the top part of the ladder, and the power is the strength applied in raising it.

4. The bones of a man's arm, and most of the moveable bones of animals, are levers of the third kind. But the loss of power in limbs of animals is compensated by the beauty and compactness of the limbs, as well as the increased velocity of their motion. The wheels in clock and watch work, and in various kinds of machinery, may be considered as levers of

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* It is on the same principle that, in raising a window, the hand should be applied to the middle of the sash, as it will then be easily raised; whereas, if the hand be applied nearer to one side than the other, the centre of gravity being unsupported, will cause the further side to bear against the frame, and obstruct its free motion.

83. What is a lever of the third kind? In what proportion must the power exceed the weight in this lever? Explain Fig. 30. Give some examples of levers of the third kind.

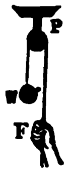
this kind, when the power that moves them acts on the pinion, near the centre of motion, and the resistance to be overcome acts on the teeth at the circumference. But here the advantage gained is the change of slow into rapid motion. The sails of vessels are constructed on the principle of the lever.*

84. The Pulley is a small wheel turning on an axis, with a string or rope in a groove running around it.

There are two kinds of pulleys—the fixed and the moveable. The fixed pulley is a pulley that has no other motion than a revolution on its axis, and it is used only for changing the direction of motion.

Fig. 31 represents a fixed pulley. P is a small wheel turning on its axis, with a string running round it in a groove. W is a weight to be raised, F is the force or power applied. It is evident that, by pulling the string at F, the weight must rise just as much as the string is drawn down. As, therefore, the velocity of the weight and the power is precisely the same, it is manifest that they balance each other, and that no mechanical advantage is gained. But this pulley is very useful for changing the direction of motion. If, for instance, we wish to raise a weight to the top of a high building, it can be done with the assistance of a fixed pulley, by a man standing below.† A curtain, or a sail, also, can be raised by means of a fixed pulley, without ascending with it, by drawing down a string running over the pulley.

Fig. 31.



85. The moveable pulley differs from the fixed pulley

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* It may perhaps assist the memory to retain the relative positions of the weight the power and the fulcrum in the three kinds of levers, if the initials be presented to the eye as follows:

First kind,	W. F. P.
Second "	F. W. P.
Third "	F. P. W.

† The fixed pulley operates on the same principle as a lever of the first kind with equal arms, where the fulcrum being in the centre of gravity, the power and the weight are equally distant from it, and no mechanical advantage is gained.

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84. What is a pulley? How many kinds of pulleys are there? What are they? What is a fixed pulley? Explain Fig. 31. What advantage is gained by this pulley? What is the use of this pulley? Upon what principle does the fixed pulley operate?

by being attached to the weight; it therefore rises and falls with the weight.

Fig. 32.

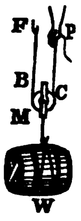
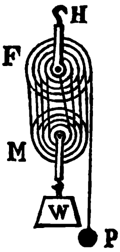


Fig. 32 represents a moveable pulley, with the weight W attached to it by a hook below. One end of the rope is fastened at F; and as the power P draws the weight upwards, the pulley rises with the weight. Now, in order to raise the weight one inch, it is evident that both sides of the string must be shortened; in order to do which, the power P must pass over two inches. As the velocity of the power is double that of the weight, it follows that a power of one pound will balance a weight on the moveable pulley of two pounds.

86. The power gained by the use of pulleys is ascertained by multiplying the number of moveable pulleys by 2.*

1. A weight of 72 pounds may be balanced by a power of 9 pounds with four pulleys; by a power of 18 pounds with two pulleys; or by a power of 36 pounds with one pulley. But in each case the space passed over by the power must be double the space passed over by the weight, multiplied by the number of moveable pulleys. That is, to raise the weight one foot, with one pulley, the power must pass over two feet, with two pulleys four feet, with four pulleys eight feet.

Fig. 33.



2. Fig. 33 represents a system of fixed and moveable pulleys In the block F, there are four fixed pulleys, and in the block M there are four moveable pulleys, all turning on their common axis, and rising and falling with the weight W. The moveable pulleys are connected with the fixed ones by a string attached to the hook H, passing over the alternate grooves of the pulleys in each block, forming eight cords, and terminating at the power P. Now to raise the weight one foot, it is evident that each of the eight cords must be shortened one foot, and, consequently, that the power P must descend eight times that distance. The

* This rule applies only to the moveable pulleys in the *same* block.

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85. How does the moveable pulley differ from the fixed pulley? Explain Fig. 32.

86. How can the power gained by the use of the moveable pulley be ascertained? What illustration of this is given? What does Fig. 33 represent?

power, therefore, must pass over eight times the distance that the weight moves.

87. Pulleys act on the same principle with the lever, the deficiency of the strength of the power being compensated by its superior velocity.

Now, as we cannot increase our natural strength, but can increase the velocity of motion, it is evident that we are enabled, by pulleys and other mechanical powers, to reduce the resistance or weight of any body to the level of our strength.

1. *Practical use of Pulleys.* Pulleys are used to raise goods into warehouses, and in ships, &c. to draw up the sails. Both kinds of pulleys are in these cases advantageously applied; for the sails are raised up to the masts by the sailors on deck, by means of the fixed pulleys, while the labor is facilitated by the mechanical power of the moveable ones.

2. Both fixed and moveable pulleys are constructed in a great variety of forms, but the principle on which all kinds are constructed, is the same. What is generally called a *tackle and fall*, or a block and tackle, is nothing more than a pulley. Pulleys have likewise lately been attached to the harness of a horse, to enable the driver to govern the animal with less exertion of strength.

3. It may be observed, in relation to the mechanical powers in general, that power is always gained at the expense of time and velocity; that is, the same power which will raise one pound in one minute, will raise two pounds in two minutes, six pounds in six minutes, sixty pounds in sixty minutes, &c.; and that the same quantity of force used to raise two pounds one foot, will raise one pound two feet, &c. And, further, it may be stated that the product of the weight, multiplied by the velocity of the weight, will always be equal to the product of the power multiplied by the velocity of the power. Hence we have the following rule. *The power is in the same proportion to the weight as the velocity of the weight is to the velocity of the power.*

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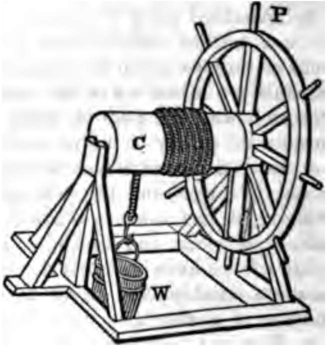
87. Upon what principle do pulleys act? What advantage is gained by the use of pulleys and other mechanical powers? What are some of the practical uses of the pulley? What is a tackle and fall? Is there any time or velocity gained by the power in the mechanical powers? To what is the product of the weight, multiplied by its velocity, always equal? What rule is given?

88. The wheel and axle consists of two wheels of different sizes, revolving together around the same centre of motion.

The place of the smaller wheel is generally supplied by a cylinder,* which forms the axle.

1. The wheel and axle, though made in many forms, will easily be understood by inspecting Figs. 34 and 35. In Fig. 34, P represents the larger wheel, where the power is applied; C the smaller wheel or cylinder, which is the axle, and W the weight to be raised. *The advantage gained is in proportion as the circumference of the wheel is greater than that of the axle.* That is, if the circumference of the wheel be six times the circumference of the axle, then a power of one pound applied at the wheel will balance a power of six pounds on the axle.

Fig. 34.



2. Sometimes the axle is constructed with a winch or handle, as in Fig. 35, and sometimes the wheel has projecting spokes, as in Fig. 34.

3. The principle upon which the wheel and axle is constructed is the same with that of the other mechanical powers, the want of power being compensated by velocity. It is evident (from the Figs. 34 and 35) that the velocity of the circumference of the wheel is as much greater than that of the axle as it is further from the centre of motion; for the wheel describes a great circle in the same time that the

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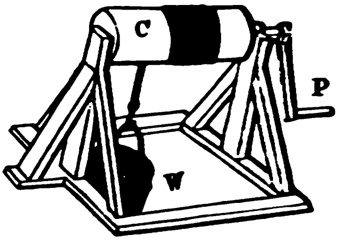
* A cylinder is a long circular body of uniform diameter, with extremities forming equal and parallel circles.

88 Of what does the wheel and axle consist? What is a cylinder? What figures illustrate the wheel and axle? Explain. To what is the advantage gained in proportion? What does Fig. 34 represent? Fig. 35? Upon what principle is the wheel and axle constructed? Explain by Figs. 34 and 35.

Fig. 25.



axle describes a small one; therefore the power is increased in the same proportion as the circumference of the wheel is greater than that of the axle. If the velocity of the wheel be twelve times greater than that of the axle, a power of one pound on the wheel will support a weight of twelve pounds on the axle.

89. The wheel and axle are constructed on the same principle with the lever; the axle acting the part of the shorter arm of the lever, the wheel that of the longer arm.

1. The capstan,* on board of ships and other vessels, is constructed on the principle of the wheel and axle. It consists of an axle placed uprightly, with a head or drum, pierced with holes for the lever, or levers, which supply the place of the wheel.

2. Windmills, lathes, the common windlass,* used for drawing water from wells, and the large wheels in mills, are all constructed on the principle of the wheel and axle.

3. Wheels are a very essential part to most machines; they are applied in different ways, but when affixed to the axle their mechanical power is always in the same proportion; that is, as the circumference of the wheel exceeds that of the axle, so much will the power be increased. Therefore the larger the wheel and the smaller the axle, the greater will be the power obtained.

4. Fly-wheels are heavy wheels used to accumulate power

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* The difference between a capstan and a windlass lies only in the position of the wheel. If the wheel turn horizontally it is called a capstan; if vertically, a windlass.

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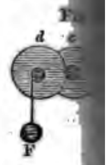
89. Upon what principle are the wheel and axle constructed? Explain how Upon what principle is the capstan on board of vessels constructed? Of what does it consist? What other things are mentioned as constructed upon this principle? Are wheels an essential part to most machines? Are they applied in more than one way? When they are affixed to the axle, in what proportion is the power increased?

and distribute it equally among all the parts They are caused to revolve by a force appli and when once set in motion continue by their for a long time. As their motion is steady and jerks, they serve to steady the power, and cause work with regularity.

5. Cranks are sometimes connected with th wheel, either to give or to receive its motion. Th by bending the axle in such a manner as to form four right angles facing in different directions, as is represented in Fig. 36. This is seen in lathes and many other kinds of machinery. Cranks are often used to change the motion from rectilinear to circular, or from circular to rectilinear.

6. In connexion with the wheel and axle, it mention the subject of complex wheel-work. It been stated that the velocity of the wheel is great of the axle; and that this velocity is in propo relative size of the wheel compared with that Advantage is taken of this circumstance in the co machinery, by such an arrangement of the parts as us to increase or lessen the speed at pleasure. evident that if the power be applied to the axle, and attached to the wheel, rapid motion will be produc the contrary, if the power be applied to the whe machinery to the axle, slow motion will be produced

7. Fig. 37 represents four wheels with their wheel acting on the axle of the adjoining wheel. F is the power applied to the axle of the wheel *d*. Now, supposing the circumference of each wheel to be six times the circumference of each axle, it is evident that each time the wheel *d* revolves it must cause the wheel *c* to make six revolutions, because the circumference of the wheel *d* is



What are fly-wheels, and for what are they used? How are to revolve? When once set in motion, what causes them to mo some time? Of what service are they in a machine? For cranks sometimes connected with the axle of a wheel? How made? What does Fig. 36 represent? For what are cranks oft How does the velocity of the wheel compare with that of the ax what is this velocity in proportion? Is any advantage taken o driving machinery where the speed is to be increased or diminishe pieces of flat glass, joined together at one side, and separated at the other by a thin strip of wood, card, or other substance. When thus prepared, immerse the glass in colored water, having previously wet the inner surface. The water will then rise between the pieces of glass, forming a beautiful curve, the higher part appearing where the pieces of glass are in contact. This is exemplified by the glass plates in the "Boston School Set."

101. The level, or equilibrium of fluids, is the tendency of the particles so to arrange themselves that every part of the surface shall be equally distant from the centre of the earth; that is, from the point to which gravity tends.

All fluids have a tendency to preserve this equilibrium. Hence the surface of all fluids, when in a state of rest must partake of the spherical form of the earth. This level or equilibrium of fluids is the natural result of the independent gravitation of each particle. The particles of a solid body being united by cohesive attraction, if any one of them be supported, it will uphold those also with which it is united. But when any particle of a fluid is unsupported, it is attracted down to the level of the surface of the fluid; and the readiness with which fluids yield to the slightest pressure will enable the particle by its own weight, to penetrate the surface of the fluid and mix with it.

102. Fluids of different densities all preserve their own equilibrium.

If a quantity of mercury, water, oil, and air, be put into the same vessel, they will arrange themselves in the order of their specific gravities. The mercury will sink to the bottom, the water will stand above the mercury, the oil above the water, and the air above the oil; and the surface of each fluid will partake of the spherical form of the earth, to which they all respectively gravitate.

103. A water-level is an instrument constructed on the

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101. What is meant by the level or equilibrium of fluids? Have all fluids a tendency to preserve this equilibrium? What follows from this? Of what is this level or equilibrium of fluids the natural result? How does the gravitation of solid bodies differ from that of fluids?

102. Do fluids of different densities all preserve their own equilibrium? What illustration is given to prove this?

principle of the equilibrium of fluids. It consists of a glass tube, partly filled with water, and closed at both ends. When the tube is not perfectly horizontal,—that is, if one end of the tube be lower than the other,—the water will run to the lower end. By this means the level of any line to which the instrument is applied may be ascertained.

Fig. 50.

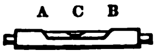

Fig. 50 represents a water-level. A B is a glass tube partly filled with water. C is a bubble of air occupying the space not filled by the water. When both ends of the tube are on a level, the air-bubble will remain in the centre of the tube; but if either end of the tube be depressed, the water will descend and the air-bubble will rise. The glass tube when used is generally set in a wooden or a brass box. It is an instrument much used by carpenters, masons, surveyors, &c.

104. Solid bodies gravitate in masses, their parts being so connected as to form a whole, and their weight may be regarded as concentrated in a point called the centre of gravity; while each particle of a fluid may be considered as a separate mass, gravitating independently.

It is for this reason that a body of water, in falling, does less injury than a solid body of the same weight. But if the water be converted into ice, the particles losing their fluid form, and being united by cohesive attraction, gravitate unitedly in one mass.

105. Fluids not only press downwards like solids, but also upwards, sidewise,* and in every direction.

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* If the particles of fluids were arranged in regular columns as in Fig. 51, there would be no *lateral* pressure; for when one particle is perpendicularly above the other, it can press only *downwards*. But if the particles be ar-

Fig. 51.

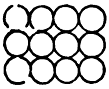
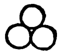


Fig. 52.



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103. Upon what principle is a water-level constructed? Of what does it consist? For what is it used? What figure represents a water-level? Explain the figure.

104. In what manner do solid bodies gravitate? What is the centre of gravity? What effect has gravity on the particles of fluids?

105. How is the pressure of fluids exerted?

So long as the equality of pressure is undisturbed, every particle will remain at rest. If the fluid be disturbed by agitating it, the equality of pressure will be disturbed, and the fluid will not rest until the equilibrium is restored.

1. The downward pressure of fluids is shown by making an aperture in the bottom of a vessel of water. Every particle of the fluid above the aperture will run downwards through the opening.
2. The lateral pressure is shown by making the aperture at the side of the vessel. The fluid will then escape through the aperture at the side.
3. The upward pressure is shown by taking a glass tube, open at both ends, inserting a cork in one end, (or stopping it with the finger,) and immersing the other in the water. The water will not rise in the tube. But the moment the cork is taken out, (or the finger removed,) the fluid will rise in the tube to a level with the surrounding water.

106. The pressure of a fluid is in proportion to the perpendicular distance from the surface; that is, the deeper the fluid the greater will be the pressure. This pressure is exerted in every direction, so that all the parts at the same depth press each other with equal force.

1. A bladder, filled with air, being immersed in water, will be contracted in size, on account of the pressure of the water

ranged as in Fig. 52, where a particle presses between two particles beneath, these last must suffer a *lateral* pressure. In whatever manner the particles are arranged, if they be globular, as is supposed, there must be spaces between them. See Fig. 1, page 20.

How long will the particles of fluids remain at rest? Explain Fig. 51. What does Fig. 52 represent? If the equality of the pressure be undisturbed, what will follow? If the fluid be agitated, when will it again come to a state of rest? How is the downward pressure of fluids shown? The lateral pressure? The upward pressure?

106. To what is the pressure of a fluid in proportion? In what direction is this pressure exerted? What illustrations are given to prove this? Why can a bottle, filled with water, or any other liquid, be let down to any depth without injury?

in all directions; and the deeper it is immersed, the more will it be contracted.

2. An empty bottle, being corked, and by means of a weight let down to a certain depth in the sea, will either be broken by the pressure, or the cork will be driven into it, and the bottle be filled with water. This will take place even if the cork be secured with wire and sealed. But a bottle filled with water, or any other liquid, may be let down to any depth without damage, because, in this case, the internal pressure is equal to the external.*

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* "*Experiments at sea.*—We are indebted t a friend, who has just arrived from Europe, says the Baltimore Gazett for the following experiments made on board the Charlemagne:

"26th of September, 1836, the weather being calm, I corked an empty wine-bottle, and tied a piece of linen over the cork; I then sank it into the sea six hundred feet; when drawn immediately up again, the cork was inside, the linen remained as it was placed, and the bottle was filled with water.

"I next made a noose of strong twine around the bottom of the cork, which I forced into the empty bottle, lashed the twine securely to the neck of the bottle, and sank the bottle six hundred feet. Upon drawing it up immediately, the cork was found inside, having forced its way by the twine, and in so doing had broken itself in two pieces; the bottle was filled with water.

"I then made a stopper of white pine, long enough to reach to the bottom of the bottle; after forcing this stopper into the bottle, I cut it off about half an inch above the top of the bottle and drove two wedges, of the same wood, into the stopper. I sank it six hundred feet, and upon drawing it up immediately the stopper remained as I placed it, and there was about a gill of water in the bottle, which remained unbroken. The water must have forced its way through the pores of the wooden stopper, although wedged as aforesaid; and had the bottle remained sunk long enough, there is no doubt that it would have been filled with water."

Similar experiments were made by the author of this work, in a voyage to the West Indies in the year 1839, first with an empty bottle and then with a bottle filled with water from the tanks on the deck; in both cases the bottle being closely stopped and the cork covered with canvass. The empty bottle was drawn from a depth of six hundred feet filled with water, and the full bottle with brackish water, the water from the tank having been compressed, and water from the depths of the ocean mixing with it.

It is the opinion of some philosophers, that the pressure at very great

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What experiment is mentioned in the note? What opinion have some philosophers expressed?

107. From what has now been stated, it appears that the lateral pressure proceeds entirely from the pressure downwards, or, in other words, from the weight of the liquid above; and that consequently the lower an orifice is made in a vessel containing water or any other liquid, the greater will be the force and velocity with which the liquid will rush out.

Fig. 53.

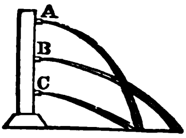

Fig. 53 represents a vessel of water, with orifices at the side at different distances from the surface. The different curves in the figure, described by the liquid in running out of the vessel, show the action of gravity and the effects produced by the force of the pressure on the liquid at different depths. At A the pressure is the least, because there is less weight of fluid above. At B and C the fluid is driven outwards by the weight of that portion above, and the force will be strongest at C.

108. As the lateral pressure arises solely from the downward pressure, it is not affected by the width nor the length of the vessel in which it is contained, but merely by its depth; for as every particle acts independently of the rest, it is only the column of particles above the orifice that can weigh upon and press out the water.

109. The lateral pressure on one side of a cubical vessel will be equal only to half of the pressure downwards; for every particle at the bottom of the vessel is pressed upon by a column of the whole depth of the fluid, while the lateral pressure diminishes from the bottom upwards to the surface, where the particles have no pressure.

depths of the sea is so great, that the water is condensed into a solid state; and that at or near the centre of the earth, if the fluid could extend so deeply, this pressure would convert the whole into a solid mass of fire.

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107. What causes the lateral pressure? What follows from this? Explain Fig. 53.

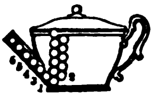
108. Does the length or the width of the vessel in which a fluid is contained have any effect upon the lateral pressure? By what is it affected?

109. How does the lateral pressure on one side of a cubical vessel compare with the pressure downwards? How would you explain this?

110. The upward pressure of fluids, although *apparently* in opposition to the principles of gravity, is but a necessary consequence of the operation of that principle; or, in other words, *the pressure upwards as well as the pressure downwards* is caused by gravity.

When water is poured into a vessel with a spout, (like a tea-pot, for instance,) the water rises in the spout to a level with that in the body of the vessel. The particles of water at the bottom of the vessel are pressed upon by the particles above them, and to this pressure they will yield, if there is any mode of making way for the particles above them. As they cannot descend through the bottom of the vessel they will change their direction and rise in the spout. Fig. 54 represents a tea-pot, and the columns of balls represent the particles of water magnified. From an inspection of the figure it appears that the particle numbered 1, at the bottom, will be pressed laterally, by the particle numbered 2, and by this pressure forced into the spout, where meeting with the particle 3 it presses it upwards, and this pressure will be continued from 3 to 4, from 4 to 5, and so on till the water in the spout has risen to a level with that in the body of the vessel. If water be poured into the spout the water will rise in the same manner in the body of the vessel; from which it appears that *the force of pressure depends entirely on the height, and not on the length or breadth of the column of fluid.*

Fig. 54.



111. One principle in hydrostatics, is so remarkable, that it is named the hydrostatic paradox. It is this. *That any quantity of fluid, however small, may be made to balance and support any other quantity, however large.*

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110. What causes the upward and downward pressure? Illustrate this by Fig. 54.

111. Upon what does the force of pressure depend? What is meant by the hydrostatic paradox? What is the use of the hydrostatic bellows? What figure represents the hydrostatic bellows? Explain the figure. What is the fundamental principle of Mechanics? Is this the principle of the hydrostatic bellows?

Fig. 55.

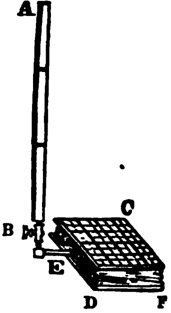

Fig. 55 represents the hydrostatic bellows.* A B is a long tube, *one inch square.* C D E F are the bellows, consisting of two boards, *eight inches square,* connected by broad pieces of leather, or india-rubber cloth, in the manner of a pair of common bellows. One pound of water poured into the tube will raise 64 pounds on the bellows. If a smaller tube be used the same quantity of water will fill it higher, and consequently will raise a greater weight; but if a larger tube be used it will of course not fill it so high, and consequently will not raise so great a weight; because it is the *height not the quantity which causes the pressure.*†

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* This is the form of the Hydrostatic bellows in the original "Boston School Set." By means of a straight jet substituted for the tube, it was designed to illustrate a principle in Hydraulics also.

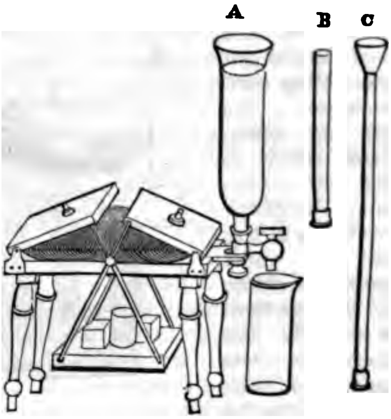
† The Hydrostatic bellows may be constructed in a variety of forms, the simplest of which consists, as in the figure, of two boards connected together by broad pieces of leather, or india-rubber cloth, in such a manner as to allow the upper board to rise and fall like the common bellows. A perpendicular tube is so adjusted to this apparatus, that water poured into the tube, passing between the boards, will separate them by its upward pressure, even although the upper board is loaded with a considerable weight.

[N. B. A small quantity of water must be poured into the bellows to separate the surfaces before they are loaded with the weight.]

The force of pressure exerted on the bellows by the water poured into the tube, is estimated by the comparative size of the tube and the bellows. Thus, if the tube be one inch square, and the top of the bellows twelve inches, thus containing 144 square inches, a pound of water poured into the tube will exert a pressure of 144 pounds on the bellows. Now it will be clearly perceived that *this pressure is caused by the height of the column of water in the tube.* A pound, or a pint of water will fill the tube 144 times as high as the same quantity would fill the bellows. To raise a weight of 144 pounds on the bellows to the height of one inch, it will be necessary to pour into the tube as much water as would fill the tube were it 144 inches long. It will thus be perceived that *the fundamental principle of the laws of motion is here also in full force; namely, that what is gained in power is lost either in time or in space;* for, while the water in the bellows is rising to the height of one inch, that in the tube passes over 144 inches.

Fig. 56 is an apparatus[*] to show that *liquids press according to the height and not the quantity.* A and B are two vessels of unequal size but of the same length. These may successively be screwed to the apparatus and filled with water. Weights may then be added to the suspended scale until the pressure is counterbalanced. It will then be perceived that although A is ten times larger than B, the water will stand at the same height in both, *because they are of the same length.* If C be used instead of A or B, the apparatus may be used as the hydrostatic bellows.

Fig. 56



112. If water be confined in any vessel, and a pressure to any amount be exerted on a square inch of that water, a pressure to an equal amount wi'l be transmitted to every square inch of the surface of the vessel in which the water is confined.[†]

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[*] This apparatus, belonging to the "Boston School Set," unites simplicity with convenience. Instead of two boards, connected with leather, an india-rubber bag is placed between two boards, and the boards are made to rise or fall as the water runs into or out of the bag. It is an apparatus easily repaired, and the bag may also be used for gas, or for experiments in Pneumatics.

[†] This property of fluids seems to invest us with a power of increasing the intensity o: a pressure exerted by a comparatively small force, without any other limit than that of the strength of the materials of which the engine itself is constructed. It also enables us with great facility to transmit

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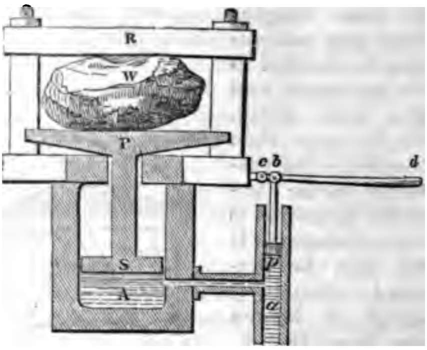
112. What fact is mentioned in this number with regard to the pressure on water?

1. It is upon this principle that Bramah's hydrostatic press, represented in Fig. 57, is constructed. The main features of this apparatus are as follows: *a* is a narrow and A a large metallic cylinder having communication one with the other. Water stands in both the cylinders. The piston S carries a strong head P, which works in a frame opposite to a similar plate, R. Between the two plates the substance W to be compressed is placed. In the narrow tube *a* is a piston *p*, worked by a lever *c b d*, its short arm *c b* driving the piston, while the power is applied at *d*. The pressure exerted by the small piston *p* on the water at *a* is transmitted with equal force throughout the entire mass of the fluid, while the surface at A presses up the piston S with a force proportioned to its area. For instance, if the cylinder *a* of the force-pump has an area of half an inch while the great cylinder has an area of 200 inches, then the pressure of the water in the latter on the piston S, will be (1 half inch multiplied by 400 half inches) equal to 400 times that on *p*.

Fig. 57



2. Next, suppose the arms of the lever to be to each other as 1 to 50, and that at *d*, the extremity of the longer arm, a

the motion and force of one machine to that of another, in cases where local circumstances preclude the possibility of instituting any ordinary mechanical connection between the two machines. Thus, merely by means of water-pipes, the force of a machine may be transmitted to any distance, and over inequalities of ground, or through any other obstructions.

Upon what principle is Bramah's hydrostatic press constructed? What figure represents this? Explain the figure. To what uses is this press applied?

man works with a force of 50 pounds, the piston *p* will consequently descend on the water with a force of 2000 pounds. Deducting $\frac{1}{4}$ for the loss of power caused by the different impediments to motion, and one man would still be able to exert a force of three quarters of a million of pounds by means of this machine. This press is used in pressing paper, cloth, hay, gunpowder, &c.; also in uprooting trees, testing the strength of ropes, &c.

113. A fluid specifically lighter than another fluid will float upon its surface.*

114. A body specifically lighter than a fluid will sink in the fluid until it has displaced a portion of the fluid equal in weight to itself.

If a piece of cork is placed in a vessel of water, about one third part of the cork will sink below, and the remainder will stand above the surface of the water; thereby displacing a portion of water equal in bulk to about a third part of the cork, and this quantity of water is equal in weight to the whole of the cork; because the specific gravity of water is about three times as great as that of cork.†

* The slaves in the West Indies, it is said, steal rum by inserting the long neck of a bottle, full of water, through the top aperture of the rum-cask. The water falls out of the bottle into the cask, while the lighter rum ascends in its stead.

† It is on the same principle that boats, ships, &c., although composed of materials heavier than water, are made to float. From their peculiar shape, they are made to set lightly on the water. The extent of the surface presented to the water counterbalances the weight of the materials, and the vessel sinks to such a depth as will cause it to displace a portion of water equal in weight to the whole weight of the vessel. From a knowledge of the specific gravity of water, and the materials of which a vessel is composed, rules have been formed by which to estimate the tonnage of vessels; that is to say, the weight which the vessel will sustain without sinking.

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113. When will one fluid float upon another?

114. What is stated with regard to a body specifically lighter than a fluid? What illustration is given of this? How do the specific gravities of water and cork compare with each other? Upon what principle is it that boats, ships, &c., are made to float upon the water? What rules have been formed from the knowledge of the specific gravity of water and the materials of which vessels are composed?

115. The standard which has been adopted to estimate the specific gravity of bodies, is rain or distilled water.[*]

Taking a certain quantity of rain or distilled water, we find that a *quantity* of gold, *equal in bulk*, will weigh nearly twenty times as much as the water; of lead, nearly twelve times as much; while oil, spirit, cork, &c., will weigh less than the water.[†]

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[*] As heat expands and cold condenses all metals, their specific gravity cannot be the same in summer that it is in winter. For this reason they will not serve as a standard to estimate the specific gravity of other bodies. The reason that *distilled* water is used is, that spring, well, or river water is seldom perfectly pure; and the various substances mixed with it affect its weight. The cause of the ascent of steam, or vapor, may be found in its specific gravity. It may here be stated that rain, snow, and hail are formed by the condensation of the particles of vapor in the upper regions of the atmosphere. Fine watery particles coming within the sphere of each other's attractions, unite in the form of a drop, which being heavier than the air, falls to the earth. Snow and hail differ from rain only in the different degrees of temperature at which the particles unite. When rain, snow, or hail fall, part of it reascends in the form of vapor, and forms clouds; part is absorbed by the roots of vegetables, and part descends into the earth and forms springs. The springs form brooks, rivulets, rivers, &c., and descend to the ocean, where being again heated by the sun, the water rising in the form of vapor, again forms clouds, and again descends in rain, snow, hail, &c. The specific gravity of the watery particles which constitute vapor, is less than that of the air near the surface of the earth; they will, therefore, ascend until they reach a portion of the atmosphere of the same specific gravity with themselves. But the constant accession of fresh vapor from the earth, and the loss of heat, causes several particles to come within the sphere of each other's attraction, as has been stated above, and they unite in the form of a drop, the specific gravity of which being greater than that of the atmosphere, it will fall in the form of rain. Water, as it descends in rain, snow, or hail, is perfectly pure, but when it has fallen to the earth, it mixes with the various substances through which it passes, which gives it a species of flavor, without affecting its transparency.

[†] The following table shows the specific gravity of the substances therein mentioned. It is to be understood that all substances whose specific gravity is greater than water, will sink when immersed in it, and that all

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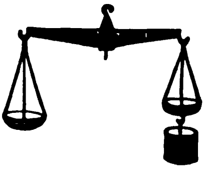
115. What standard has been adopted to estimate the specific gravity of substances in general? Why could not metals have been adopted? Why is distilled water used? What bodies will sink when immersed in water? What will float?

116. The specific gravity of bodies that will sink in water is ascertained by weighing them first in water, and then out of the water, and dividing the weight out of the water by the loss of weight in water.

Fig. 58.



1. Fig. 58 represents the scales for ascertaining the specific gravity of bodies. One scale is shorter than the other, and a hook is attached to the bottom of the scale to which substances, whose specific gravity is sought, may be attached and sunk in water.

2. Suppose a cubic inch of gold weighs 19 ounces when weighed out

whose specific gravity is less than that of water, will float in it. Let us then take a quantity of water which will weigh exactly one pound; a quantity of the substances specified in the table, of the same bulk, will weigh as follows:

Platinum, -	23. lbs.	Chalk, - - -	1.793 lbs.	Living men, -	.891 lbs.
Fine Gold, -	19.640 "	Coal, - - -	1.250 "	Ash, - - - -	.800 "
Mercury, -	14.019 "	Mahogany, -	1.063 "	Beech, - - -	.700 "
Lead, - - -	11.525 "	Milk, - - -	1.034 "	Elm, - - - -	.600 "
Silver, - -	11.091 "	Box-wood, -	1.030 "	Fir, - - - -	.500 "
Copper, - -	9.000 "	Rain water, -	1.000 "	Cork, - - - -	.240 "
Iron, - - -	7.645 "	Oil, - - - -	.920 "	Common air, -	.0011 "
Glass, - - -	3.000 "	Ice, - - - -	.908 "	Hydrogen gas,	.000105
Marble, - -	2.705 "	Brandy, - -	.820 "		

A cubic foot of water weighs one thousand avoirdupois ounces. By multiplying the number opposite to any substance in the above table by one thousand, we obtain the weight of a cubic foot of that substance, in ounces. Thus, a cubic foot of platinum is 23000 ounces in weight.

In the above table it appears that the specific gravity of *living men* is about one ninth less than that of common water. So long, therefore, as the lungs can be kept free from water, a person, although unacquainted with the art of swimming, will not completely sink, provided the hands and arms be kept under water.

The specific gravity of sea water is greater than that of the water of lakes and rivers, on account of the salt contained in it. On this account the water of lakes and rivers has less buoyancy, and it is more diffiult to swim in it.

What is the weight of a cubic foot of water? What is the use of the above table? How does the specific gravity of living men compare with that of water? Which is the greater, the specific gravity of sea water, or of lakes and rivers? Why?

116. How is the specific gravity of bodies that will sink in water ascertained? What illustration is given? Explain Fig 58

of the water, and but 18 ounces* when weighed in water—the loss in water is one ounce. The weight out of water, 19 ounces, being divided by one (the loss in water) gives 19. The specific gravity of gold, then, would be 19, or, in other words, gold is nineteen times heavier than water.

117. The specific gravity of a body that will not sink in water, is ascertained by dividing its weight by the sum of its weight, added to the loss of weight which it occasions in a heavy body previously balanced in water.†

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* The gold will weigh less in the water than out of it, on account of the upward pressure of the particles of water, which in some measure supports it, and by so doing diminishes its weight. Now, as the upward pressure of these particles is exactly sufficient to balance the downward pressure of a quantity of water of exactly the same dimensions with the gold, it follows that the gold will lose exactly as much of its weight in water, as a quantity of water of the same dimensions with the gold will weigh. And this rule applies to all bodies heavier than water, that are immersed in it. *They will lose as much of their weight in water as a quantity of water of their own dimensions weighs.* All bodies, therefore, of the same size, lose the same quantity of their weight in water. Hence, *the specific gravity of a body is the weight of it compared with that of water.* As a body loses a quantity of its weight when immersed in water, it follows that when the body is lifted from the water, that portion of its weight which it had lost will be restored. This is the reason that a bucket of water, drawn from a well, is heavier when it rises above the surface of the water in the well, than it is while it remains below the surface. For the same reason our limbs feel heavy in leaving a bath.

† The method of ascertaining the specific gravities of bodies was discovered accidentally by Archimedes. He had been employed by the king of Syracuse to investigate the metals of a golden crown which he suspect-

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Why will gold weigh less in the water than out of it? How does this upward pressure of the particles compare with the downward pressure of a quantity of water of the same dimensions? What follows from this? What rule is given with regard to all bodies heavier than water that are immersed in it? What is the specific gravity of a body? What is the reason that a bucket of water, drawn from a well, is heavier when it rises above the surface of the water, than while it is below it?

117. How can the specific gravity of a body that will not sink in water be ascertained? What illustration is given? By whom was the method of ascertaining the specific gravities of bodies discovered? In what manner did he ascertain it?

If a body lighter than water weighs six ounces, and on being attached to a heavy body, balanced in water, is found to occasion it to lose twelve ounces of its weight, its specific gravity is determined by dividing its weight (six ounces) by the sum of its weight, added to the loss of weight it occasions in the heavy body, namely, six added to twelve, which, in other words, is 6 divided by 18, or $\frac{6}{18}$, which is $\frac{1}{3}$.

118. An hydrometer is an instrument to ascertain the specific gravity of liquids.

1. The hydrometer is constructed on the principle, that the greater the weight of a liquid, the greater will be its buoyancy.

2. The hydrometer is made in a variety of forms, but it generally consists of a hollow ball of silver, glass, or other material, with a graduated scale rising from the upper part. A weight is attached below the ball. When the instrument, thus constructed, is immersed in a fluid, the specific gravity of the fluid is estimated by the portion of the scale that remains above the surface of the fluid. The greater the specific gravity of the fluid, the less will the scale sink.

ed had been adulterated by the workmen. The philosopher labored at the problem in vain, till going one day into the bath, he perceived that the water rose in the bath in proportion to the bulk of his body. He instantly perceived that any other substance of equal size would raise the water just as much, though one of *equal* weight and *less* bulk could not produce the same effect. He then obtained two masses, one of gold and one of silver, each equal in weight to the crown, and having filled a vessel very accurately with water, he first plunged the silver mass into it, and observed the quantity of water that flowed over; he then did the same with the gold, and found that a less quantity had passed over than before. Hence he inferred that, though of equal weight, the bulk of the silver was greater than that of the gold, and that the quantity of water displaced was, in each experiment, equal to the bulk of the metal. He next made trial with the crown, and found that it displaced more water than the gold, and less than the silver, which led him to conclude, that it was neither pure gold nor pure silver.

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118. What is an hydrometer? Upon what principle is it constructed? Explain its construction. In what proportion does the scale sink?

CHAPTER VI.

HYDRAULICS.

119. Hydraulics treats of the motion of fluids, particularly of water; and the construction of all kinds of instruments and machines for moving them.

Water, in its motion, is retarded by the friction of the bottom and sides of the channel through which it passes. For this reason the velocity of the surface of a running stream is always greater than that of any other part.*

120. A fluid running from an orifice in a vessel is discharged with the greater rapidity when the vessel from which it flows is kept constantly full.

This is a necessary consequence of the law, that pressure is proportioned to the height of the column above.

121. When a fluid spouts from several orifices in the side of a vessel, it is thrown to the greatest distance from the orifice nearest to the centre.†

122. A vessel filled with any liquid will discharge a greater quantity of the liquid through an orifice to which

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* In consequence of the friction of the banks and beds of rivers, and the numerous obstacles they meet in their circuitous course, their progress is slow. If it were not for these impediments, the velocity which the waters would acquire would produce very disastrous consequences. An inclination of three inches in a mile, in the bed of a river, will give the current a velocity of about three miles an hour.

† This is true only on the condition that the vessel be not elevated. If the vessel be elevated, the lowest orifice will discharge the fluid to the greatest distance, but when the vessel is placed low, the fluid will reach the plane before its projectile force is expended.

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119. Of what does Hydraulics treat? What retards the motion of water? Why does the surface of a canal or river have a greater velocity than any other part?

120. Does the fulness of a vessel from the orifice of which a fluid is running, have any effect upon its velocity?

121. When a fluid spouts from several orifices in the side of a vessel, from which is it thrown to the greatest distance?

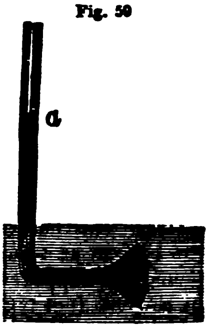
a short pipe of peculiar shape is fitted, than through an orifice of the same size without a pipe.* But if the pipe project into the vessel, the quantity discharged will be diminished instead of increased by the pipe.

The quantity of a fluid discharged through a pipe or an orifice is increased by heating the liquid; because heat diminishes the cohesion of the particles, which exists, to a certain degree, in all liquids.

123. The velocity of a current of water may be ascertained by immersing in it a bent tube, shaped like a tunnel at the end which is immersed.

Fig. 59 is a tube shaped like a tunnel, with the larger end immersed in an opposite direction to the current. The rapidity of the current is estimated by the height to which the water is forced into the tube, above the surface of the current. By such an instrument the comparative velocity of different streams, or the same stream at different times, may be estimated.†

Fig. 59



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* This is caused by the cross-currents made by the rushing of the water from different directions towards the sharp-edged orifice. The pipe smooths the passage of the liquid.

† To measure the velocity of a stream at its surface, hollow floating bodies are used; as, for example, a glass bottle filled with a sufficient quantity of water to make it sink just below the level of the current, and having a small flag projecting from the cork. A wheel may also be caused to revolve by the current striking against boards projecting from the circumference of the wheel, and the rapidity of the current may be estimated by the number of the revolutions in a given time.

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122. What effect will a pipe, fitted to an orifice, have with regard to the quantity discharged? What will be the effect if the pipe project into the vessel? How can the quantity discharged through a pipe or orifice, be increased? Why will heat increase it?

123. How can the velocity of a current of water be ascertained? What does Fig. 59 represent? How is the rapidity of the current estimated? What is the use of the instrument?

146. The impenetrability of air prevents the ascent of water into any inverted vessel, unless the air is first permitted to escape.

1. If a tube, closed at one end, or an inverted tumbler, be inserted at its open end, in a vessel of water, the water will not rise in the tube or tumbler, to a level with the water in the vessel, on account of the impenetrability of the air within the tube. But if the tube be open at both ends, the water will rise, because the air can escape through the upper end. It is on this principle that the diving-bell (or the diver's bell, as it is sometimes called) is constructed.

2. Fig. 71 represents a diving-bell. It consists of a large heavy vessel, formed like a bell, (but may be made of any other shape,) with the mouth open. It descends into the water with

lons of water in the space of twelve hours. His experiment was thus made: he put a glass, mouth downwards, on a grass-plot, on which it had not rained for above a month. In less than two minutes the inside was covered with vapor; and in half an hour drops began to trickle down its inside. The mouth of the glass was 20 square inches. There are 1296 square inches in a square yard, and 4840 square yards in an acre. When the glass had stood a quarter of an hour, he wiped it with a piece of muslin, the weight of which had been previously ascertained. When the glass had been wiped dry, he again weighed the muslin, and found that its weight had been increased six grains by the water collected from 20 square inches of earth; a quantity equal to 1600 gallons, from an acre, in 12 hours. Another experiment, after rain had fallen, gave a much larger quantity. (See No. 9.)

When the atmosphere is colder than the earth, the vapor, which arises from the ground, or a body of water, is condensed and becomes visible This is the way that fog is produced. When the earth is colder than the atmosphere, the moisture in the atmosphere condenses in the form of dew, on the ground, or other surfaces.

Clouds are nothing more than vapor, condensed by the cold of the upper regions of the atmosphere.

Rain is produced by the sudden cooling of large quantities of watery vapor.

Snow and hail are produced in a similar manner, and differ from rain only in the degree of cold which produces them.

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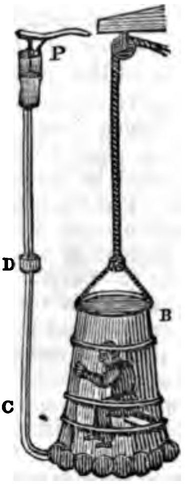
146. Is air impenetrable, like other substances? How is this shown? Upon what principle is the diving-bell constructed? What figure represents the diving-bell? Why does not the water rise in the bell? Explain the figure.

Fig. 71.



its mouth downwards. The air within it having no outlet is compelled, by the order of specific gravities, to ascend in the bell, and thus (as water and air cannot occupy the same space at the same time) prevents the water from rising in the bell. A person, therefore, may descend with safety in the bell to a great depth in the sea, and thus recover valuable articles that have been lost. A constant supply of fresh air is sent down, either by means of barrels, or by a forcing-pump. In the Fig., B represents the bell with the diver in it. C is a bent metallic tube attached to one side and reaching the air within; and P is the forcing-pump through which air is forced into the bell. The forcing-pump is attached to the tube by a joint at D. When the bell descends to a great depth, the pressure of the water condenses the air within the bell, and causes the water to ascend in the bell. This is forced out by constant accessions of fresh air, supplied as above mentioned. Great care must be taken that a constant supply of fresh air is sent down, otherwise the lives of those within the bell will be endangered. The heated and impure air is allowed to escape through a stop-cock in the upper part of the bell.

147. Water is raised in the common pump by means of the pressure of the atmosphere on the surface of the water. A vacuum being produced by raising the piston or pump-box,* the water below is forced up by the atmospheric pressure, on the principle of the equilibrium

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* In order to produce such a vacuum, it is necessary that the piston or box should be accurately fitted to the bore of the pump; for if the air above the piston has any means of rushing in to fill the vacuum, as it is produced by the raising of the piston, the water will not ascend. The piston is generally worked by a lever, which is the handle of the pump, not represented in the figure.

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147. By what means is water raised in the common pump? How is the pressure removed?

CHAPTER VIII.

ACOUSTICS.

152. Acoustics is the science which treats of the nature and laws of sound. It includes the theory of musical concord or harmony.

153. Sound is caused by a tremulous or vibratory motion of the air.

1. If a bell be rung under an exhausted receiver, no sound can be heard from it; but when the air is admitted to surround the bell, the vibrations immediately produce sound.

2. Again, if the experiment be made by enclosing the bell in a small receiver, full of air, and placing that under another receiver, from which the air can be withdrawn; though the bell, when struck, must then produce sound, as usual, yet it will not be heard if the outer receiver be well exhausted, and care be taken to prevent the vibrations from being communicated through any solid part of the apparatus; because there is no medium through which the vibrations of the bell, in the smaller receiver, can be communicated to the ear.

154. Sounds are louder when the air surrounding the sonorous body is dense, than when it is in a rarefied state.

For this reason the sound of a bell is louder in cold than in warm weather; and sound of any kind is transmitted to a greater distance in cold, clear weather, than in a warm sultry day. On the tops of mountains, where the air is rare, the human voice can be heard only at the distance of a few rods; and the firing of a gun produces a sound scarcely louder than the cracking of a whip.

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152. What is that science called which treats of the nature and laws of sound? What does it include?

153. What causes sound? What illustrations are given to prove this?

154. In what proportion are sounds loud or faint? Why does a bell sound louder in cold than in warm weather? Why is sound fainter on the top of a mountain than near the surface of the earth?

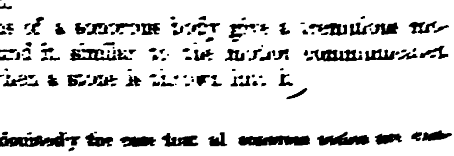
155. Sonorous bodies are those which produce clear, distinct, regular, and durable sounds, such as a bell, a drum, wind instruments, musical strings, and glasses. These vibrations can be communicated to a distance not only through the air, but also through liquids and solid bodies.

156. Bodies owe their sonorous property to their elasticity.*

157. The sound produced by a musical string is caused by its vibrations; and the height or depth of the tone depends upon the rapidity of these vibrations. Long strings vibrate with less rapidity than short ones, and for this reason the low tones in a musical instrument proceed from the long strings, and the high tones from the short ones.

1. Fig. 92, A B represents a musical string. If it be drawn up to G, its elasticity will not only carry it back again, but will give it a momentum which will carry it to H, from whence it will successively return to T, F, C, D, &c., until the resistance of the air entirely destroys its motion.

Fig. 92.



2. The vibrations of a sonorous body give a tremulous motion to the air around it, similar to the motion communicated to smooth water when a stone is thrown into it.

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* Although it is undoubtedly the case that all sonorous bodies are elastic, it is not to be inferred that all elastic bodies are sonorous.

155. What are sonorous bodies?
156. To what do sonorous bodies owe their sonorous property? Are all elastic bodies sonorous?
157. What causes the sound produced by a musical string? Upon what does the height and depth of the tone depend? Which strings, in a musical instrument, produce the low tones? Why? Explain Fig. 92.

and the force or direction of the wind makes but slight difference in its velocity.

2. This uniform velocity of sound enables us to determine the distance of an object from which it proceeds. If, for instance, the light of a gun, fired at sea, be seen a half of a minute before the report is heard, the vessel must be at the distance of six miles and a half. In the same manner, the distance of a thunder-cloud may be ascertained, by counting the seconds between the appearance of the lightning and the noise of the thunder, and multiplying them by 1142 feet.

164. An echo is produced by the vibrations of the air meeting a hard and regular surface, such as a wall, a rock, a mountain, and being reflected back to the ear, thus producing the same sound a second, and sometimes a third and fourth time.*

1. Speaking-trumpets are constructed on the principle of the reflection of sound.

2. The voice, instead of being diffused in the open air, is

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* From this it is evident that no echo can be heard at sea, or on an extensive plain; because there is no object there to reflect the sound. An echo is heard only when a person stands in such a situation as to hear both the original and the reflected sound. The pupil will doubtless recollect what has been said in Mechanics with respect to the angles of incidence and reflection. Sound (as well as light, as will be explained under the head of Optics) is communicated and reflected by the same law, namely, that *the angles of incidence and reflection* are always equal. It is not difficult, therefore, to ascertain the direction in which sound will proceed, whether it be direct or reflected. It is related of Dionysius, the tyrant of Sicily, that he had a dungeon, (called the ear of Dionysius,) in which the roof was so constructed as to collect the words, and even the whispers, of the prisoners confined therein, and direct them along a hidden conductor to the place where he sat to listen: and thus he became acquainted with the most secret expressions of his unhappy victims.

What advantage results from this uniform velocity of sound? How can the distance of a thunder-cloud be ascertained?

164. How is an echo produced? *Note.* Why cannot an echo be heard at sea, or on an extensive plain? How must a person stand in order to hear an echo? By what law is sound communicated and reflected? What anecdote is related of Dionysius? Upon what principle are speaking-trumpets constructed? Explain the manner in which the vibrations of the air are reflected.

confined within the trumpet; and the vibrations which spread and fall against the sides of the instrument are reflected according to the angle of incidence, and fall in the direction of the vibrations, which proceed straight forward. The whole of the vibrations are thus collected into a focus; and if the ear be situated in or near that spot, the sound will be prodigiously increased.

3. Hearing-trumpets, or the trumpets used by deaf persons, are also constructed on the same principle; but as the voice enters the large end of the trumpet instead of the small one, it is not so much confined, nor so much increased.

4. The musical instrument called the trumpet, acts also on the same principle with the speaking-trumpet, so far as its form tends to increase the sound.*

165. Sound, like light, after it has been reflected from several surfaces, may be collected into one point, as a focus, where it will be more audible than in any other part; and on this principle whispering-galleries may be constructed.

The famous whispering-gallery in the dome of St. Paul's church, in London, is constructed on this principle.† Persons at very remote parts of the building can carry on a conversation in a soft whisper, which will be distinctly audible to one another, while others in the building cannot hear it; and the ticking of a watch may be heard from side to side.

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* The smooth and polished surface of the interior parts of certain kinds of shells, particularly if they be spiral or undulating, fit them to collect and reflect the various sounds which are taking place in the vicinity. Hence the Cyprias, the Nautilus, and some other shells, when held near the ear, give a continued sound, which resembles the roar of the distant ocean.

† There is a church in the town of Newburyport, in Massachusetts, which, as was accidentally discovered, has the same property as a whispering-gallery. Persons in opposite corners of the building, by facing the wall, may carry on a conversation in the softest whisper, unheard by others in any other part of the building. It is the building which contains in its cemetery the remains of the distinguished preacher, Whitefield.

Upon what principle are hearing-trumpets constructed? How far does the musical instrument, called the trumpet, act upon the principle of the speaking-trumpet? *Note.* How can the continued sound given by some shells, when held near the ear, be explained?

165. Upon what principle may whispering-galleries be constructed?

1. Thus, woollen garments are warm garments, because they part slowly with the heat which they acquire from the body, and, consequently, they do not readily convey the warmth of the body to the air; while, on the contrary, a linen garment is a cool one, because it parts with its heat readily, and as readily receives fresh heat from the body. It is, therefore, constantly receiving heat from the body and throwing it out into the air, while the woollen garment retains the heat which it receives, and thus encases the body with a warm covering.

2. For a similar reason ice, in summer, is wrapped in woollen cloths. It is then protected from the heat of the air, and will not melt.

172. Heat is propagated in two ways, namely, by conduction and by radiation. Heat is propagated by conduction when it passes from one substance to another in contact with it. Heat is propagated by radiation when it passes through the air or any other elastic fluid.

173. Different bodies conduct heat with different degrees of facility. The metals are the best conductors, and among metals silver is the best conductor.

1. For this reason any liquid may be heated in a silver vessel more readily than in any other of the same thickness. The metals stand in the following order, with respect to their conducting power; namely, silver, gold, tin, copper, platina, steel, iron, and lead.

2. It is on account of the conducting power of metals* that

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* Metals, on account of their conducting power, cannot be handled when raised to a temperature above 120 degrees of Fahrenheit. Water becomes scalding hot at 150 degrees, but air, heated far beyond the temperature of boiling water, may be applied to the skin without much pain. Sir Joseph Banks, with several other gentlemen, remained some time in a room when the heat was 52 degrees above the boiling point; but, though they could bear the contact of the heated *air*, they could not touch any metallic substance, as their watch-chains, money, &c. Eggs, placed on

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172. In what two ways is heat propagated? When is it propagated by conduction? When is it propagated by radiation?

173. Do all bodies conduct heat with the same degree of facility? What bodies are the best conductors? In what order do the metals stand with respect to their conducting power?

the handles of metal tea-pots and coffee-pots are commonly made of wood; since, if they were made of metal, they would become too hot to be grasped by the hand, soon after the vessel is filled with heated fluid. Wood conducts heat very imperfectly. For this reason wooden spoons and forks are preferred for ice. Indeed, so imperfect a conductor of heat is wood, that a stick of wood may be grasped by the hand while one end of the stick is a burning coal. Animal and vegetable substances, of a loose texture, such as fur, wool, cotton, &c., conduct heat very imperfectly; hence their efficacy in preserving the warmth of the body.

174. Heat is reflected from bright surfaces; while black or dark colored bodies absorb the heat that falls on them.

1. This is the reason why the bright brass andirons, or any other bright substances, placed near a hot fire, seldom become heated; while other dark substances, further removed from the fire, become too hot for the hand.

2. Snow or ice will melt under a piece of black cloth, when it will remain perfectly solid under a white one. The farmers in some of the mountainous parts of Europe, are accustomed to spread black earth, or soot, over the snow, in the spring, to hasten its melting, and enable them to commence ploughing early.

175. All bodies, when violently compressed or extended, become warm.

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a tin frame, were roasted hard in twenty minutes; and a beef-steak was overdone in thirty-three minutes.

Chantrey, the celebrated sculptor, had an oven which he used for drying his plaster cuts and moulds. The thermometer generally stood at 300 degrees in it, yet the workmen entered, and remained in it some minutes without difficulty; but a gentleman once entering it with a pair of silver-mounted spectacles on, had his face burnt where the metal came in contact with the skin.

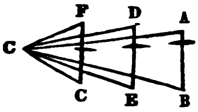
Is wood a good conductor of heat? Why are wool, fur, &c., so efficacious in preserving the warmth of the body? What is related in the note with regard to the conducting power of heat?

174. What bodies reflect the heat? What bodies absorb the heat? Why do bright bodies, when placed near the fire, seldom become heated? Will snow melt most readily under white or black cloth?

175. What effect is produced on all bodies when violently compressed or extended?

figure it is evident, that the nearer an object is to the eye, the wider must be the opening of the lines to admit the extremities of the object; and, consequently, the larger the angle under which it is seen; and, on the contrary, that objects at a distance will form small angles of vision. Thus, in this figure, the three crosses, F G, D E, and A B, are all of the same size; but A B, being the most distant, subtends the smallest angle* A C B, while D E and F G, being nearer to the eye, situated at C, form respectively the larger angles, D C E and F C G.

Fig. 105.



214. When an object, at any distance, does not subtend an angle of more than two seconds of a degree, it is invisible.

At the distance of four miles a man of common stature will thus become invisible, because his height at that distance will not subtend an angle of two seconds of a degree. The size of

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* The apparent size of an object depends upon the size of the angle of vision. But we are accustomed to correct, by experience, the fallacy of appearances; and, therefore, since we know that real objects do not vary in size, but that the angles under which we see them do vary with the distance, we are not deceived by the variations in the appearance of objects. Thus, a house at a distance appears absolutely smaller than the window through which we look at it; otherwise we could not see it through the window; but our knowledge of the real size of the house prevents our alluding to its apparent magnitude. In Fig. 104 it will be seen that the several crosses, AB, DE, FG, and HI, although very different in size, on account of their different distances, subtend the same angle A C B; they, therefore, all appear to the eye to be of the same size, while, in Fig. 105, the three objects AB, DE, and FG, although of the same absolute size, are seen at a different angle of vision, and they, therefore, will seem of different sizes, appearing larger as they approach the eye.

It is upon a correct observance of the angle of vision that the art of perspective drawing is indebted for its accuracy.

What effect has the nearness of the object to the eye, on the angle? Illustrate this by the figure. Upon what does the apparent size of an object depend? Why do objects appear so large? To what is the art of perspective drawing indebted for its accuracy?

214. How large an angle must a body subtend to be visible?

the apparent diameter of the heavenly bodies is generally stated by the angle which they subtend.

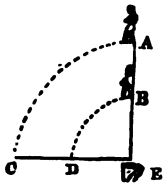
215. When the velocity of a moving body does not exceed twenty degrees in an hour, its motion is imperceptible to the eye.

1. It is for this reason that the motion of the heavenly bodies is invisible, notwithstanding their immense velocity.

2. The real velocity of a body in motion round a point, depends on the space comprehended in a degree. The more distant the moving body from the centre, or, in other words, the larger the circle which it has to describe, the larger will be the degree.

3. In Fig. 106, if the man at A, and the man at B, both start together, it is manifest that A must move more rapidly than B, to arrive at C at the same time that B reaches D; because the arc A C is the arc of a larger circle than the arc B D. But to the eye at E, the velocity of both appears to be the same, because both are seen under the same angle of vision.

Fig. 106.



216. There are three kinds of mirrors,* namely, the plain, the concave, and the convex mirror.

Plain mirrors are those which have a flat surface, such as a common looking-glass; and they neither

* A mirror is a smooth and polished surface, that forms images by the reflection of the rays of light. Mirrors (or looking-glasses) are made of glass, with the back covered with an amalgam, or mixture of mercury and tinfoil. It is the smooth and bright surface of the mercury that reflects the rays, the glass acting only as a transparent case, or covering, through which the rays find an easy passage. Some of the rays are absorbed in their passage through the glass, because the purest glass is not free from imperfections. For this reason, the best mirrors are made of fine and highly-polished steel.

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215. When is the motion of a body invisible? Why is the motion of the heavenly bodies invisible? Upon what does the real velocity of a body, in motion round a point, depend? Explain Fig. 106. Why does the velocity of both, to an eye at E, appear to be the same?

216. How many kinds of mirrors are there? What are plain mirrors? Do they magnify or diminish the object?

object; the image is then formed by light reflected *from* the object, instead of being transmitted through it.

2. The magnifying power of a single microscope is ascertained by dividing the least distance at which an object can be distinctly seen by the naked eye, by the focal distance of the lens. This, in common eyes, is about 7 inches. Thus, if the focal distance of a lens be only $\frac{1}{4}$ of an inch, then the *diameter* of an object will be magnified 28 times, (because 7, divided by $\frac{1}{4}$, is the same as multiplying 7 by 4,) and the *surface* will be magnified 784 times.

3. The magnifying power of the compound microscope is found in a similar manner, by ascertaining the magnifying power, first of one lens, and then of the other.

4. The magnifying power of the solar microscope is in proportion as the distance of the image, from the object-glass, is greater than that of the object itself from it. Thus, if the distance of the object from the object-glass be $\frac{1}{4}$ of an inch, and the distance of the image, or picture, on the screen, be ten feet, or 120 inches, the object will be magnified in length 480 times, or, in surface, 230,000 times.*

238. The magic lantern is an instrument constructed on the principle of the solar microscope, but the light is supplied by a lamp instead of the sun.

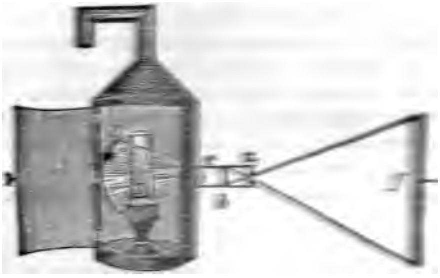
1. The objects to be viewed by the magic lantern are generally painted with transparent colors, on glass slides, which are received into an opening in the front of the lantern. The light from the lamp, in the lantern, passes through them, and carries the pictures, painted on the slides, through the lenses, by means of which a magnified image is thrown upon the wall, on a white surface prepared to receive it.

* A lens may be caused to magnify or to diminish an object. If the object be placed at a distance from the focus of a lens, and the image be formed in or near the focus, the image will be diminished; but if the object be placed near the focus, the image will be magnified.

How is the image then formed? How is the magnifying power of a single microscope ascertained? Illustrate this. How is the magnifying of the compound microscope ascertained? In what proportion is the magnifying power of the solar microscope? Illustrate this. *Note.* How may a lens be made to magnify or diminish an object?

238. What is the magic lantern? How are objects, viewed by the magic lantern, generally represented?

2. Fig. 128 represents the magic lantern. The rays of light from the lamp are received upon the concave mirror [illegible] and re-



flected to the convex lens c, which is called the condenser, [illegible] because it concentrates a large quantity of light upon the [illegible] painted on the slide, inserted at b. The rays from the illuminated object at b, are carried divergent through the lens, forming an image on the screen at d. The image will increase or diminish in size, in proportion to the distance of the screen from the lens *a*.

239. A telescope is an instrument for viewing distant objects.

There are two kinds of telescopes, namely, the refracting telescope and the reflecting telescope.

A refracting telescope is one in which the object itself is viewed, through the medium of a number of lenses.

A reflecting telescope is one in which the image of the object is reflected from a concave mirror, within the tube of the telescope, and viewed through a number of lenses.*

* The image of the object seen through a refracting telescope is never so clear and perfect as that obtained by the reflecting telescope; because

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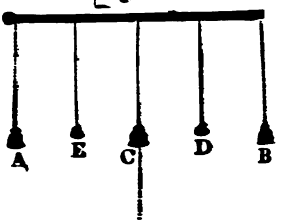
What figure represents a magic lantern? Explain the figure. In what proportion will the size of the image increase or diminish?

239. What is a telescope? How many kinds of telescopes are there? What are they? What is a refracting telescope? What is a reflecting telescope? *Note.* Why is the image of an object, seen through a refracting telescope, less clear and perfect than when seen through a reflecting telescope?

266. The electrical bells are designed to show the effects of electrical attraction and repulsion.

1. They are thus to be applied.* The ball B of the prime conductor, with its rod, is to be unscrewed, and the rod on which the bells are suspended is to be screwed in its place. The middle bell is to be connected by a chain with the table or the floor. When the machine is turned, the balls suspended between the bells will be alternately attracted and repelled by the bells, and cause a constant ringing. If the battery be charged and connected with the prime conductor, the bells will continue to ring until all the fluid from the battery has escaped.

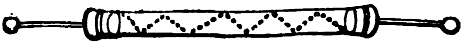
Fig. 129.



It may be observed, that the fluid from the prime conductor passes readily from the two outer bells, which are suspended by chains; they, therefore, attract the two balls towards them. The balls becoming electrified by contact with the outer bells, are repelled by them and driven to the middle bell, to which they communicate their electricity; having parted with their electricity they are repelled by the middle bell, and again attracted by the outer ones, and thus the constant ringing is maintained. The fluid which is communicated to the middle bell, is conducted to the earth by the chain attached to it.

2. SPIRAL TUBE. The passage of the electric fluid from one conducting substance to another, is beautifully exhibited by means of a glass tube having a brass ball at each end, and

Fig. 130.



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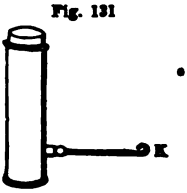
* In some sets of instruments, the bells are insulated on a separate stand; but the mode described above is a convenient mode of connecting them with the prime conductor.

266. What are the electrical bells? What figure represents them? What are they designed to show? How are they to be applied? Explain the spiral tube.

coated in the inside with small pieces of tinfoil, placed at small distances from each other in a spiral direction, as represented in Fig. 130.

In the same manner various figures, letters, and words may be represented, by arranging similar pieces of tinfoil between two pieces of flat glass. These experiments appear more brilliant in a darkened room.)

Fig. 131



3. **Hydrogen Pistol.** (Fig. 131 represents a hydrogen pistol.* When filled with hydrogen gas,† if the insulated knob K be presented to the prime conductor, it will immediately explode.

4. Electrical Sportsman. Fig. 133 represents the electrical sportsman. From the larger ball of a Leyden jar two birds

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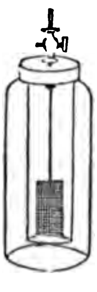
* This apparatus is made in a variety of forms, sometimes in the exact form of a pistol, and sometimes in the form of a piece of ordnance. The form in the figure is a simple and cheap contrivance, and is sufficient to explain the manner in which the instrument is to be used in any of its forms.

† A very convenient and economical way of procuring hydrogen gas for this and other experiments, is by means of *the hydrogen gas generator*, as represented in Fig. 132. It consists of a glass vessel, with a brass cover, in the centre of which is a stop-cock; from the inside of the cover, another glass vessel is suspended, with its open end downwards. Within this, a piece of zinc is suspended by a wire. The outer vessel contains a mixture of sulphuric acid and water, about nine parts of water to one of acid. When the cover, to which the inner glass is firmly fixed, is placed upon the vessel, the acid acting upon the zinc, causes the metal to absorb the oxygen of the water, and the hydrogen, the other constituent part of the water, being thus disengaged, rises in the inner glass, from which it expels the water; and when the stop-cock is turned the hydrogen gas may be collected in the hydrogen pistol, or any other vessel. In the use of hydrogen gas for explosion, it will be necessary to dilute the gas with an equal portion of atmospheric air.

Fig. 132



Explain the hydrogen pistol.

285. Heat weakens, and a great degree of heat destroys the power of a magnet; but the magnetic attraction is undiminished by the interposition of any bodies, except iron, steel, &c.

Electricity frequently changes the poles of a magnet; and the explosion of a small quantity of gunpowder, on one of the poles, produces the same effect.

Electricity, also, sometimes renders iron and steel magnetic, which were not so before the charge was received.

286. The effect produced by two magnets, used together, are much more than double that of either one used alone.

When a magnet is suspended freely from its centre, the two poles will not lie in the same horizontal direction. This is called the inclination or *the dipping* of the magnet.*

287. The magnet, when suspended, does not invariably point *exactly* to the north and south points, but varies a little towards the east or the west. This variation differs at different places, at different seasons, and at different times in the day.†

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* The tendency of a magnetic needle to dip is corrected in the mariner's and surveyor's compasses, by making the south ends of the needles intended for use in northern latitudes somewhat heavier than the north ends. Compass-needles, intended to be employed on long voyages where great variations of latitude may be expected, are furnished with a small sliding weight, by the adjusting of which the tendency *to dip* may be counteracted. The cause of the dipping of the needle is the superior attraction caused by the closer proximity of the pole of the magnet to the magnetic pole of the earth. In north latitude, the north pole of the needle dips; in south latitude, the south pole.

† The variation of the magnetic needle from what has been supposed its true polarity, was a phenomenon that for centuries had baffled the

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285. What effect has heat on the power of the magnet? By what is the magnetic attraction diminished? What effect has electricity on the poles of a magnet? What effect has electricity sometimes on iron and steel?

286. What proportion do the effects produced by two magnets, used together, bear to that of either, used alone? What is meant by the inclination or dipping of the magnet?

287. Does the magnet, when suspended, invariably point to the north and south points?

1. The science of magnetism has rendered immense advantages to commerce and navigation, by means of the mariner's compass.* The mariner's compass consists of a magnetized bar of steel, called a *needle;* having at its centre a cap fitted to it,

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science of the philosopher to explain. Recent discoveries have given a satisfactory explanation of this apparent anomaly. The earth has, in fact, four magnetic poles, two of which are strong and two are weak. The strongest north pole is in America, the weakest in Asia. The earth itself is considered as a magnet, or rather, as composed in part of magnetic substances, so that its action at the surface is irregular. The variation of the needle from the true geographical meridian is therefore subject to changes more or less irregular.

This subject is very ably treated in "Davis' Manual of Magnetism," (edition of 1847,) to which the student is referred, as probably the best treatise on the subject that has ever been published. Mr. Davis is one of those scientific and skilful mechanics, (of whom there are not a few among us,) who have, as it were, forced their way into the temple of science amid discouragements and difficulties, but have deposited richer gifts on the altar than most of those whose contributions were expected. He has originated many improvements in this department of science; and his devotion to the subject has probably rendered him as familiar with all the peculiar phenomena relating to it, as any one in or out of the country. His address is, Daniel Davis, Jr., Magnetical Instrument Maker, 428 Washington-street, Boston.

* The invention of the mariner's compass is usually ascribed to Flavio de Melfi, or Flavio Gioia, a Neapolitan, about the year 1302. Some authorities, however, assert that it was brought from China by Marco Paolo, a Venetian, in 1260. The invention is also claimed both by the French and English.

The value of this discovery may be estimated from the consideration, that, before the use of the compass, mariners seldom trusted themselves out of sight of land; they were unable to make long or distant voyages, as they had no means to find their way back. This discovery enabled them to find a way where all is trackless; to conduct their vessels through the mighty ocean, out of the sight of land; and to prosecute those discoveries, and perform those gallant deeds, which have immortalized the names of Cook, of La Perouse, Vancouver, Sir Francis Drake, Nelson, Parry, Franklin, and others.

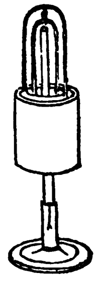
What advantage has the science of magnetism rendered to commerce and navigation? Of what does the mariner's compass consist? *Note.* To whom is the invention of the mariner's compass usually ascribed? How may the value of this discovery be estimated?

should also be amalgamated. Beneath the hanging wire, a small circular magnet is fixed in the socket of the cup *b*, so that one of its poles is a little above the mercury. As in the former cup, a metallic connexion is made through the bottom, from the mercury to the external wire.) end

If now the poles of a battery be connected with the horizontal external wires, *c c*, the current of electricity will be through the mercury and the horizontal wire, on the pillar which connects them, and it will now be found, that the moveable part of the wire will rotate around the magnetic pole in the cup *b*, and the magnetic pole round the fixed wire in the other cup *a*, in the direction before mentioned.

By using a very delicate apparatus, the magnetic pole of the earth may be made to put the wire in motion.

Fig. 146.



3. Fig. 146 represents another ingenious contrivance, invented by M. Ampère, for illustrating the electro-magnetic rotation; and it has the advantage of comprising within itself the voltaic combination which is employed. It consists of a cylinder of copper about two inches high, and a little less than two inches internal diameter, within which is a small cylinder, about one inch in diameter. The two cylinders are connected together by a bottom, having an aperture in its centre the size of the smaller cylinder, leaving a circular cell, which may be filled with acid. A piece of strong copper wire is fastened across the top of the inner cylinder, and from the middle of it rises, at a right angle, a piece of copper wire, supporting a very small metal cup, containing a few globules of mercury. A cylinder of zinc, open at each end, and about an inch and a quarter in diameter, completes the voltaic combination. To the latter cylinder a wire, bent like an inverted U, is soldered at opposite sides; and in the bend of this wire a metallic point is fixed, which, when inserted in the little cup of mercury, suspends the zinc cylinder in the cell, and allows it a free circular motion. An additional point is directed down-

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If the poles of a battery be connected with the horizontal external wires, *c c*, throughout, what direction will the current of electricity take? Round what pole will the moveable part of the wire rotate? Round what will the magnetic pole rotate? What does Fig. 146 represent? Of what does it consist?

wards from the central part of the stronger wire, which point is adapted to a small hole at the top of a powerful bar magnet. When the apparatus with one point only is charged with diluted acid, and set on the magnet placed vertically, the zinc cylinder revolves in a direction determined by the magnetic pole which is uppermost. With two points, the copper revolves in one direction, and the zinc in a contrary direction.

4. If, instead of a bar magnet, a horse-shoe magnet be employed, with an apparatus on each pole similar to that which has now been described, the cylinders in each will revolve in opposite directions. The small cups of mercury mentioned in the preceding description are sometimes omitted, and the points are inserted in an indentation on the inverted U.*

296. The magnetizing power of the conducting wires of a battery is very greatly increased by coiling it into a helix, into which the body to be magnetized may be inserted. A single circular turn is more efficient than a straight wire, and each turn adds to the power within a certain limit, whether the whole forms a single layer, or whether each successive turn encloses the previous one.

1. When a helix of great power is required, it is composed of several layers of wire. The wire forming the coil must be insulated by being wound with cotton, to prevent any lateral passage of the current.

2. Fig. 147 represents a helix on a stand. A bar of soft iron, N S, being placed within the helix, is connected with the

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* The phenomenon of electro-magnetic rotation is beautifully illustrated by Mr. Davis, in his treatise on Magnetism, to which reference has already been made. He has invented and prepared a great variety of ingenious contrivances for the illustration of this subject, and his book should be in the hands of all who desire a thorough acquaintance with all that has been discovered in the new department of science in which magnetism and electricity are combined. The author has been indebted to Mr. Davis' volume for a number of explanations which are incorporated in this work.

How will the cylinders in each revolve, if, instead of a bar-magnet, a horse-shoe magnet be employed, with an apparatus on each pole similar to that which has now been described?

296. How may the magnetizing power of the connecting wires be increased? Is a single circuit preferable to a straight wire? Explain Fig. 147.

the Earth has one, Jupiter four, Saturn seven, and Uranus six; and

Of an unknown number of comets.*

The stars, which we see in the night time, are supposed to be suns, surrounded by systems of planets, too distant to be seen from the earth. Although they appear so numerous on a bright night, they become much more so by the aid of glasses.

305. The planets† may be distinguished from the stars by their *steady* light; while the stars appear to twinkle. The planets, likewise, seem to change their relative places in the heavens, while those luminous bodies which are called *fixed* stars appear to preserve the same relative position.

1. The sun, the moon, the planets, and the fixed stars, which appear to us so small, are supposed to be large worlds, of various sizes, and at different but immense distances from us. The reason that they appear to us so small is, that on account of their immense distances they are seen under a small angle of vision.

2. It has been stated in the early pages of this book, that *every portion of matter* is attracted by every other portion,— and that the force of the attraction depends upon the *quantity*

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* The planet Neptune, so recently discovered, is undoubtedly attended by his secondaries or moons, two of which have already been discovered. Whether more will ever be discovered, is a question which remains for the future astronomer to answer.

† The meaning of the word planet is properly a *wanderer*, or a *wandering star*. These luminaries were so called because they never retain the same situation, but are constantly changing their relative positions; while those stars which appear to retain their places are called *fixed stars*. The cause of the motion of the planets will be presently explained.

What are the stars supposed to be? Do we see more by the aid of glasses than without?

305. How may the planets be distinguished from the stars? How are the planets distinguished from the *fixed* stars? What is the meaning of the word planet? Why are they called planets? What are the fixed stars? What are the sun, moon, planets, and fixed stars supposed to be? Why do they appear so small? What has been stated with regard to the attraction of portions of matter? Upon what force does this attraction depend?

of matter and the *distance.* As attraction is *mutual*, we find that all of the heavenly bodies attract the earth; and the earth, likewise, attracts all of the heavenly bodies. It has been proved, that a body when actuated by several forces will not obey *either one*, but will move in a direction *between* them. It is so with the heavenly bodies,—each one of them is attracted by every other one; and these attractions are so nicely balanced by creative wisdom, that, instead of rushing together in one mass, they are caused to move in regular paths, (called *orbits*,) around a central body; which being attracted in *different* directions, by the bodies which revolve around it, will itself revolve around the centre of gravity of the system. Thus, the sun is the centre of what is called the *solar* system, and the planets revolve around it in different times, at different distances, and with different velocities.

306. The paths or courses in which the planets move around the sun are called their orbits.

1. In obedience to the universal law of gravitation, the planets revolve around the sun as the centre of their system; and the time that each one takes to perform an entire revolution is called its year. Thus, the planet Mercury revolves around the sun in 87 of our days. Hence, a year on that planet is equal to 87 days. The planet Venus revolves around the sun in 224 days. That is, therefore, the length of the year of that planet. Our earth revolves around the sun in about 365 days and 6 hours. Our year, therefore, is of that length.

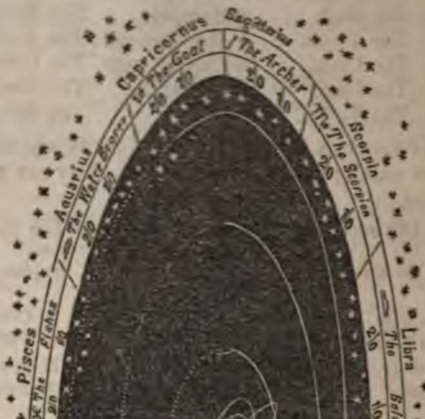
2. The length of time that each planet takes in performing its revolution around the sun, or, in other words, the length of the year on each planet, is as follows. (*The fractional parts of the day are omitted.*)

What follows from attraction being mutual? What direction do bodies take when actuated by several forces? Is this true with regard to the heavenly bodies? What is the centre of the solar system? What is said of the revolution of the planets?

306. What are the paths in which the planets move around the sun called? Around what do the planets revolve? What is a year on each planet? How long is the year of the planet Mercury? How long is the planet Venus performing her revolution around the sun? How long is the earth performing her revolution around the sun? What is the length of the year on the planet Mercury? Venus? Earth? Mars? Vesta? Juno? Ceres? Pallas? Jupiter? Saturn? Herschel? Neptune?

ecliptic, the orbits of all the primary planets, and of the comet of 1680. That part of each orbit which is above the plane i

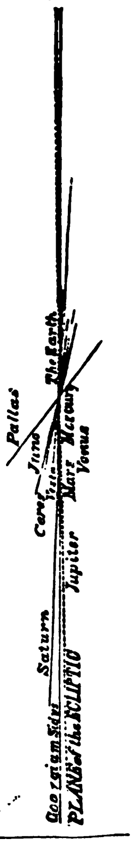
Fig. 152.



shown by a white line; that which is below it, by a dark That part of the orbit of each planet where it crosses ecliptic, or, in other words, where the white and dark lines in the figure meet, are called the nodes of the planet, from the Latin *nodus*, a knot or tie.

2. Fig. 153 represents a section of the plane of the ecliptic, showing the inclination of the orbits of the planets. As the zodiac extends only eight degrees on each side of the ecliptic, it appears from the figure that the orbits of some of the planets are wholly in the zodiac, while those of others rise above and descend below it. Thus, the orbits of Juno, Ceres, and Pallas, rise above, while those of all the other planets are confined to the zodiac.

Fig. 153.



312. When a planet or heavenly body is in that part of its orbit which appears to be near any particular constellation, it is said to be in that constellation.

Thus, in Fig. 152, the comet of 1680 appears to approach the sun from the constellation Leo.

313. The perihelion* and aphelion* of a heavenly body express its situation with regard to the sun. When a body is nearest to the sun, it is said to be in its perihelion. When farthest from the sun, it is said to be in its aphelion.

The earth is three millions of miles nearer to the sun in its perihelion than in its aphelion.

314. The apogee* and perigee* of a

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* The plural of *Perihelion* is *Perihelia*, and of *Aphelion* is *Aphelia*. When a planet is so nearly on a line with the earth and the sun as to pass between them, it is said to be in its *inferior conjunction*; when behind the sun, it is said to be in its *superior conjunction*; but when behind the earth, it is said to be in *opposition*.

What does Fig. 152 represent? What are the nodes of a planet? What does Fig. 153 represent?

312. When is a planet said to be in any particular constellation?

313. What do the perihelion and aphelion of a heavenly body express? When is a body said to be in its perihelion? When is a body said to be in its aphelion? How much nearer is the earth to the sun in its perihelion than in its aphelion?

sun's attraction becomes stronger, on account of the nearness of the earth; and, consequently, in its motion from L to E, the earth will move with greater rapidity. At E, which is the perihelion of the earth, it acquires its greatest velocity. Let us now detain it at E, merely to consider the direction of the forces by which it is urged. If the sun's attraction could be destroyed, the force which has carried it from L to E, would carry it off in the dotted line from E to G, which is a tangent to its orbit. But while the earth has this tendency to move towards G, the sun's attraction is continually operating with a tendency to carry it to S. Now, when a body is urged by two forces, it will move between them; but as the sun's attraction is constantly exerted, the direction of the earth's motion will not be in a straight line, the diagonal of *one* large parallelogram, but through the diagonal of a number of infinitely small parallelograms; which, being united, form the curve line E A.

It is thus seen, that, while the earth is moving from L to E, the attraction of the sun is stronger than in any other part of its orbit, and will cause the earth to move rapidly. But in its motion from E to A, from A to B, from B to C, and from C to F, the attraction of the sun, operating in an opposite direction, will cause its motion from the sun to be retarded, until, at F, the direction of its motion is reversed, and it begins again to approach the sun. Thus, it appears that, in its passage from the perihelion to the aphelion, the motion of the earth, as well as that of all the heavenly bodies, must be constantly retarded; while, in moving from their aphelion to perihelion, it is constantly accelerated; and at their perihelion, the velocity will be the greatest. The earth, therefore, is about seven days longer in performing the aphelion part of its orbit, than in traversing the perihelion part; and the revolution of all the other planets being the result of the same cause, is affected in the same manner as that of the earth.

319. The earth is about three millions of miles nearer to the sun in winter than in summer.

What is said of the motion of the heavenly bodies from perihelion to aphelion? What is their motion from aphelion to perihelion? When is their velocity the greatest? How much longer is the earth in performing the aphelion part of its orbit than the perihelion part?

319. How much nearer is the earth to the sun in winter than in summer?

The heat of summer, therefore, cannot be caused by the near approach of the earth to the sun.

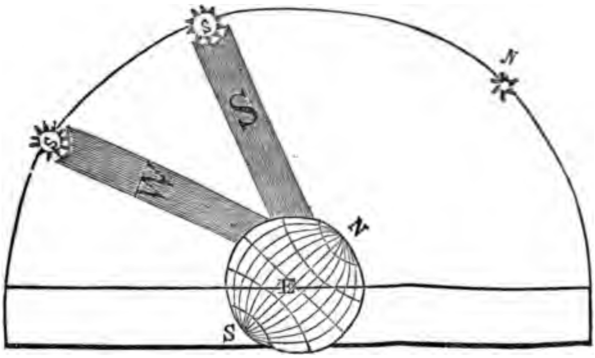
Snow and ice never melt on the tops of high mountains; and they who have ascended in the atmosphere, in balloons, have found that the cold increases as they rise.

320. On account of the inclination of the earth's axis, the rays of the sun fall more or less obliquely on different parts of the earth's surface, at different seasons of the year. The heat is always the greatest when the sun's rays fall *vertically;* and the more obliquely they fall, the less heat they appear to possess.

1. This is the reason why the days are hottest in summer, although the earth is farther from the sun at that time.

2. Fig. 155 represents the manner in which the rays of the sun fall upon the earth in summer and in winter. The north pole of the earth, at all seasons, constantly points to the north

Fig. 155.



star N; and when the earth is nearest to the sun, the rays from the sun fall as indicated by W, in the figure; and as their direction is very oblique, and they have a larger portion

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320. What follows from the inclination of the earth's axis, with regard to the direction of the sun's rays? When is the heat always the greatest? What is said of oblique rays? What is the reason that the heat is greater in summer than in winter? Illustrate this by Fig. 155. How is the earth situated with regard to its distance from the sun in winter?

Circle is within the line of perpetual darkness, the sun can shine on no part of it. It will, therefore, be constant night to all places within that circle. As the whole of the Arctic Circle is within the line of perpetual light, no part of that circle will be turned from the sun while the earth turns on its axis. To all places, therefore, within the Arctic Circle, it will be constant day.

On the 22d of September, when the earth is at C, its axis is neither inclined *to* nor *from* the sun, but is sidewise; and, of course, while one half of the earth, from pole to pole, is enlightened, the other half is in darkness, as would be the case if its axis were perpendicular to the plane of its orbit; and it is this which causes the days and nights, of this season of the year, to be of equal length.

On the 23d of December, the earth has progressed in its orbit to B, which causes the whole space within the northern polar circle to be continually in darkness, and more of that part of the earth north of the equator to be in the shade than in the light of the sun. Hence, on the 21st of December, at all places north of the equator, the days are shorter than the nights, and at all places south of the equator, the days are longer than the nights. Hence, also, within the Arctic Circle it is uninterrupted night, the sun not shining at all; and within the Antarctic Circle it is uninterrupted day, the sun shining all the time.

On the 20th of March, the earth has advanced still further, and is at A, which causes its axis, and the length of the days and nights, to be the same as on the 20th of September.*

23½ degrees *from* the sun, when the days are the shortest. Thus, as the earth progresses in its orbit, after the days are the shortest, it changes its inclination towards the sun, till it is again inclined as in the longest days in the summer

* As the difference in the length of the days and the nights, and the change of the seasons, &c., on the earth, is caused by the inclination of the earth's axis, it follows that all the planets, whose axes are inclined, must experience the same vicissitude; and that it must be in proportion to

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Explain, by the figure, the situation of the earth on the 22d of September. On the 23d of December. On the 20th of March. What follows from the changes on the earth, caused by the inclination of the earth's axis? In what proportion are these changes? What is said of the axis of the planet Jupiter?

9. From the explanation of figure 157, it appears that there are two parts of its orbit in which the days and nights are equal all over the earth. These points are in the sign of Aries and Libra, which are therefore called the equinoxes. Aries is the vernal (or spring) equinox, and Libra the autumnal equinox.

10. There are also two other points called **solstices**, because the sun appears to *stand* at the *same height* in the heavens, in the middle of the day, for several days. These points are in the signs Cancer and Capricorn. Cancer is called the summer solstice, and Capricorn the winter solstice.

321. The sun is a spherical body, situated near the centre of gravity of the system of planets of which our earth is one.

1. Its diameter is 877,547 English miles; which is equal to 100 diameters of the earth; and, therefore, his cubic magnitude must exceed that of the earth one million of times.* It

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the degree of the inclination of their axes. As the axis of the planet Jupiter is nearly perpendicular to its orbit, it follows that there can be little variation in the length of the days, and little change in the seasons of that planet.

There can be little doubt that the sun, the planets, stars, &c., are all of them inhabited; and although it may be thought that some of them, on account of their immense distance from the sun, experience a great want of light and heat, while others are so near, and the heat consequently so great that water cannot remain on them in a fluid state, yet as we see, even on our own earth, that creatures of different natures live in different elements, as, for instance, fishes in water, animals in air, &c., creative wisdom could, undoubtedly, adapt the being to its situation, and with as little exertion of power, form a race whose nature should be adapted to the nearest or the most remote of the heavenly bodies, as was required to adapt the fowls to the air, or the fishes to the sea.

* Spheres are to each other as the cubes of their respective diameters.

Note. Is it supposed that the sun, planets, and stars are inhabited? What is shown by Fig. 157? Where are these points? What are they called? Which is the vernal equinox? Which the autumnal? What other two points are there? Why are they called solstices? Where are these points? Which is the summer solstice? Which the winter?

321. What is said of the sun? What is its diameter? How much does its cubic magnitude exceed that of the earth?

revolves around its axis in 25 days and 10 hours. This has been ascertained by means of several dark spots which have been seen with telescopes on its surface.

2. Dr. Herschel supposed the greater number of spots on the sun to be mountains; some of which he estimated to be 300 miles in height.

3. It is probable that the sun,* like all the other heavenly bodies, (excepting, perhaps, comets,) is inhabited by beings whose nature is adapted to their peculiar circumstances.

4. Although, by some, the sun is supposed to be an immense ball of fire, on account of the effects produced at the distance of ninety-five millions of miles, yet many facts show that heat is produced by the sun's rays only when they act on a suitable medium. Thus, snow and ice remain during the year on the tops of the highest mountains, even in climates where the cold of our winters is never known.

5. The zodiacal light is a singular phenomenon, accompanying the sun. It is a faint light which often appears to stream up from the sun a little after sunset and before sunrise. It appears nearly in the form of a cone, its sides being somewhat curved, and generally but ill defined. It extends often from 50° to 100° in the heavens, and always nearly in the direction of the plane of the ecliptic. It is most distinct about the beginning of March; but is constantly visible in the torrid zone. The cause of this phenomenon is not known.

322. Mercury is the nearest planet to the sun, and is seldom seen; because his vicinity to the sun occasions his being lost in the brilliancy of the sun's rays.

1. The heat of this planet is so great that water cannot exist there, except in a state of vapor; and metals would be melted. The intenseness of the sun's heat, which is in the same proportion as its light, is seven times greater in Mercury

* In almanacs, the sun is usually represented by a small circle, with the face of a man in it, thus: ☉

How long is it in performing its revolution around its axis? How has this been ascertained? What did Dr. Herschel suppose these spots to be? What is the zodiacal light? At what time is it most distinct? Where is it constantly visible?

322. What planet is nearest to the sun? Why is it seldom seen? What is said of the heat of this planet? How much greater is the sun's heat in Mercury than on the earth?

than on the earth; so that water there would be carried off in the shape of steam: for, by experiments made with a thermometer, it appears that a heat seven times greater than that of the sun's beams in summer, will make water boil.

2. Mercury, although in appearance only a small star, emits a bright white light by which it may be recognised when seen. It appears a little before the sun rises, and again a little after sunset, but as its angular distance from the sun never exceeds 23 degrees, it is never to be seen longer than one hour and fifty minutes after sunset; nor longer than that time before the sun rises.

3. When viewed through a good telescope, Mercury appears with all the various phases, or increase and decrease of light, with which we view the moon; except that it never appears quite full, because its enlightened side is turned directly towards the earth only when the planet is so near the sun as to be lost to our sight in its beams. Like that of the moon, the crescent or enlightened side of Mercury is always towards the sun. As no spots are commonly visible on the disk, the time of its rotation on its axis is unknown.

323. Venus,* the second planet in order from the sun, is the nearest to the earth, and on that account appears to be the largest and most beautiful of all the planets. During a part of the year it rises before the sun, and it is then called the morning star; during another part of the year it rises after the sun, and it is then called the evening star. The heat and light at Venus are nearly double what they are at the earth.

* By the ancient poets, Venus was called *Phosphor*, or *Lucifer*, when it appeared to the west of the sun, at which time it is morning star, and ushers in the light or day; and *Hesperus* or *Vesper*, when eastward of the sun, or evening star.

In what form does water exist in Mercury? How can Mercury be recognised when seen? At what time does it appear? How does Mercury appear when viewed through a telescope?

323. What planet is nearest to the earth? When is Venus called the morning star? When is it called the evening star? How much greater are the light and heat at Venus than that at the earth? What name was given by the ancient poets to Venus, when morning star? What, when evening star?

1. Venus, like Mercury, presents to us all the appearances of increase and decrease of light common to the moon. Spots are also sometimes seen on its surface, like those on the sun. By reason of the great brilliancy of this planet, it may sometimes be seen even in the daytime, by the naked eye.* But it is never seen late at night, because its angular distance from the sun never exceeds 45 degrees. In the absence of the moon it will cast a shadow behind an opaque body.

2. Both Mercury and Venus sometimes pass directly between the sun and the earth. As their illuminated surface is towards the sun, their dark side is presented to the earth, and they appear like dark spots on the sun's disk. This is called the transit of these planets.

324. The earth is the next planet, in the solar system, to Venus. It is not a perfect sphere, but its figure is that of an *oblate spheroid*, the equatorial diameter being about 34 miles longer than its polar diameter.

It is attended by one moon, the diameter of which is about two thousand miles. Its mean distance from the earth is about 240,000 miles, and it turns on its axis in precisely the same time that it performs its revolution round the earth; namely, in twenty-nine days and a half.

325. *The earth, when viewed from the moon, exhibits precisely the same phases that the moon does to us, but in opposite order. When the moon is full to us, the earth will be dark to the inhabitants of the moon; and when the moon is dark to us, the earth will be full to*

What is the greatest distance at which the planets, Mercury and Venus, ever appear from the sun? What is meant by the transit of these planets? What is said of the different appearances which Venus presents? Why can we not see the planets and stars in the daytime?

324. What planet is next to Venus? What is the form of the earth? How much larger is its equatorial diameter than its polar? How many moons has the earth? What is the diameter of the moon? What is its distance from the earth? What is the length of a day at the moon? How long is it in performing its revolution around the earth?

325. What phases does the earth, when viewed from the moon, exhibit?

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* The reason why we cannot see the stars and planets in the daytime, is, that their light is so faint, compared with the light of the sun reflected by our atmosphere

them. The earth appears to them about 13 times larger than the moon does to us. As the moon, however, always presents nearly the same side to the earth, there is one-half of the moon which we never see, and from which the earth cannot be seen.

326. Next to the earth is the planet Mars. It is conspicuous for its fiery red appearance; which is supposed to be caused by a very dense atmosphere.

1. When this planet approaches any of the fixed stars, they change their color, grow dim, and often become totally invisible. This is supposed to be caused by his atmosphere. The degree of heat and light at Mars is less than half of that received by the earth.

2. The four small planets, or asteroids, Vesta, Juno, Ceres, and Pallas, have all been discovered within the present century. Vesta was discovered by Dr. Olbers, of Bremen, in 1807: its light is pure and white. Juno, by Mr. Harding, near Bremen, in 1804: its color is red, and its atmosphere appears cloudy. Pallas was discovered by Dr. Olbers in 1802: it appears to have a dense, cloudy atmosphere. Ceres was discovered at Palermo, in Sicily, by Piazzi, in 1801: it is of a ruddy color. All of these small planets undergo various changes in appearance and size, so that their real magnitude is not ascertained with any certainty; and but little is known of them.*

* It is a remarkable fact, that certain irregularities, observed in the motions of the old planets, induced some astronomers to suppose that a planet existed between the orbits of Mars and Jupiter; a supposition that arose long previous to the discovery of the four new planets just noticed. The opinion has been advanced, that these four small bodies originally composed one larger one, which, by some unknown force, or convulsion, burst asunder. This opinion is maintained with much ingenuity and plau-

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How much larger does the earth appear than the moon?

326. What planet is next to the earth? What renders it conspicuous? What is supposed to cause this appearance? How much more light and heat does the earth enjoy than Mars? When were the asteroids discovered? By whom, and in what year was Vesta discovered? What is the color of its light? By whom and when was Juno discovered? What is the color of its light? When was Pallas discovered? By whom? What is said of its atmosphere? When and by whom was Ceres discovered? What is its color? What is said in the note with regard to these planets?

327. Jupiter is the largest planet of the solar system, and the most brilliant, except Venus. The heat and light at Jupiter is about 25 times less than that at the earth. This planet is attended by four moons, or satellites; the shadows of some of which are occasionally visible upon his surface.

1. The distance of those satellites from the planet are two, four, six, and twelve hundred thousand miles, *nearly*.

The nearest revolves around the planet in less than two days; the next in less than four days; the third in less than eight days; and the fourth in *about* sixteen days.

2. These four moons must afford considerable light to the inhabitants of the planet; for the nearest appears to them four times the size of our moon; the second about the same size; the third somewhat less; and the fourth about one-third the diameter of our moon.

3. As the axis of Jupiter is nearly perpendicular to its orbit, it has no sensible change of seasons.

4. The satellites of Jupiter often pass behind the body of the planet, and also into its shadow, and are eclipsed. These eclipses are of use in ascertaining the longitude of places on the earth. By these eclipses also, it has been ascertained that light is about eight minutes in coming from the sun to the earth. For, an eclipse of one of these satellites appears to us to take place sixteen minutes sooner, when the earth is in that part of its orbit nearest Jupiter, than when in the part farthest from that planet. Hence, light is sixteen minutes in crossing the earth's orbit, and of course half of that time, or eight minutes, in coming from the sun to the earth.

sibility by Dr. Brewster, in the Edinburgh Encyclopedia, *Art.* ASTRONOMY. Dr. Brewster further supposes, that the bursting of this planet may have occasioned the phenomena of meteoric stones; that is, stones which have fallen on the earth from the atmosphere

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327. Which of the planets is the largest? How much more light and heat does the earth enjoy than Jupiter? How many moons has this planet? What is the distance of these moons from the planet? In what time do they perform their revolutions around the planet? How does the size of these moons compare with that of ours? Why has Jupiter no sensible variety of seasons? Of what use are the eclipses of Jupiter's moons? How long is light in coming from the sun to the earth? How has this been ascertained?

5. When viewed through a telescope, several belts or bands are distinctly seen, sometimes extending across his disk, and sometimes interrupted and broken. They differ in distance, position, and number. They are generally dark; but white ones have been seen.

6. On account of the immense distance of Jupiter from the sun, and also from Mercury, Venus, the Earth, and Mars, observers on Jupiter, with eyes like ours, can never see either of the above-named planets, because they would always be immersed in the sun's rays.

328. Saturn is the second in size and the last but one in distance from the sun. The degree of heat and light at this planet is eighty times less than that at the earth.

1. Saturn is distinguished from the other planets by being encompassed by two large, luminous rings. They reflect the sun's light in the same manner as his moons. They are entirely detached from each other and from the body of the planet. They turn on the same axis with the planet, and in nearly the same time.* The edge of these rings is constantly at right angles with the axis of the planet. Stars are sometimes seen between the rings, and also between the inner ring and the body of the planet. The breadth of the two rings is about the same as their distance from the planet, namely, 21,000 miles. As they cast shadows on the planet, Dr. Herschel thinks them solid.

2. The surface of Saturn is sometimes diversified, like that of Jupiter, with spots and belts. Saturn has seven satellites, or moons, revolving around him at different distances, and in various times, from less than one to eighty days.

3. Saturn may be known by his pale and steady light. The

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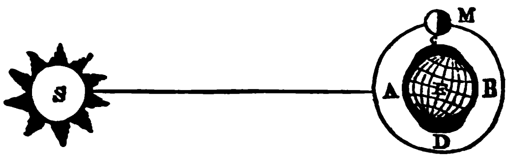
* These rings move together around the planet, but are about *thirteen minutes* longer in performing their revolution about him, than Saturn is in revolving about his axis.

How does Jupiter appear when viewed through a telescope?

328. How does Saturn compare in size with the other planets? How is Saturn distinguished from the other planets? What is said of these rings? How much longer are these rings in performing their revolution around the planet than the planet is in performing its revolution on its axis? What is the breadth of these rings? What is said of the surface of Saturn? How many moons has Saturn? How may Saturn be known?

sun and moon being in lines at right angles tend to raise tides

Fig. 161.



at different places; namely, the moon at C and D, and the sun at A and B. Tides that are produced when the moon is in its quarters, are low, and are called *neap* tides.*

OF ECLIPSES.

337. An eclipse is a total or partial obscuration of one heavenly body by the intervention of another.

1. The situation of the earth with regard to the moon, or rather of the moon with regard to the earth, occasions eclipses both of the sun and moon. Those of the sun take place when the moon, passing between the sun and earth, intercepts his rays. Those of the moon take place when the earth, coming between the sun and moon, deprives the moon of his light. Hence, an eclipse of the sun can take place only when the moon changes, and an eclipse of the moon only when the moon fulls;

* There are so many natural difficulties to the free progress of the tides, that the theory by which they are accounted for is, in fact, and necessarily, the most imperfect of all the theories connected with astronomy. It is, however, indisputable, that the moon has an effect upon the tides, although it be not equally felt in all places, owing to the indentations of the coast, the obstructions of islands, continents, &c., which prevent the free motion of the waters. In narrow rivers, the tides are frequently very high and sudden, from the resistance afforded by their banks to the free ingress of the water, whence what would otherwise be a tide, becomes an accumulation. It has been constantly observed, that the spring tides happen at the new and full moon, and the neap tides at the quarters. This circumstance is sufficient in itself to prove the connexion between the influence of the moon and the tides.

What are neap tides? When do they take place?

337. What is an eclipse? When does an eclipse of the sun take place? When does an eclipse of the moon take place?

for *at the time of an eclipse,* either of the sun or the moon, *the sun, earth, and moon must be in the same straight line.*

2. If the moon revolved around the earth in the same plane in which the earth revolves around the sun, that is, in the ecliptic, it is plain that the sun would be eclipsed at every new moon; and the moon would be eclipsed at every full. For at each of these times, these three bodies would be in the same straight line. But the moon's orbit does not coincide with the ecliptic, but is inclined to it at an angle of about $5^\circ 20'$. Hence, since the apparent diameter of the sun is but about ½ a degree, and that of the moon about the same, no eclipse will take place at new or full moon, unless the moon be within ½ a degree of the ecliptic, that is, in or near one of its nodes. It is found that if the moon be within $16\frac{1}{2}^\circ$ of a node at time of change, it will be so near the ecliptic, that the sun will be more or less eclipsed; if within 12° at time of full, the moon will be more or less eclipsed.

3. It is obvious that the moon will be oftener within $16\frac{1}{2}^\circ$ of a node at the time of change, than within 12° at the time of full; consequently there will be more eclipses of the sun than of the moon in a course of years. As the nodes commonly come between the sun and earth but twice in a year, and the moon's orbit contains 360°, of which $16\frac{1}{2}^\circ$, the *limit* of solar eclipses, and 12°, the *limit* of lunar eclipses, are but small portions, it is plain there must be many new and full moons without any eclipses.

4. Although there are more eclipses of the sun than of the moon, yet more eclipses of the moon will be visible at a particular place, as Boston, in a course of years, than of the sun. Since the sun is very much larger than either the earth or moon, the shadow of these bodies must always terminate in a point; that is, it must always be a cone. In Fig. 162, let S be the sun, *m* the moon, and E the earth. The sun constantly illuminates half the earth's surface, that is, a hemisphere; and consequently it is visible to all in this hemisphere. But the

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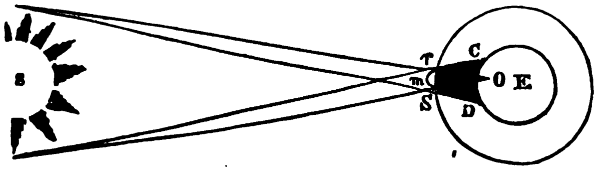
What is necessary at the time of an eclipse? How often would there be an eclipse, if the moon went round the earth in the same plane in which the earth goes round the sun? Why? What is the inclination of the moon's orbit to the ecliptic? What is the apparent diameter of the sun and moon? What follows from this? When is the sun eclipsed? When the moon? Does an eclipse happen every time there is a full or new moon? What must the shadows of these bodies always be? Why?

moon's shadow falls upon a part only of this hemisphere; and hence the sun appears eclipsed to a part only of those to whom

Fig. 162.



it is visible. Sometimes, when the moon is at its greatest distance, its shadow, O *m*, terminates before it reaches the earth. In eclipses of this kind, to an inhabitant directly under the point O, the outermost edge of the sun's disk is seen, forming a bright ring around the moon; from which circumstance these eclipses are called *annular*, from *annulus*, a Latin word for ring.

Besides the dark shadow of the moon, *m* O, in which all the light of the sun is intercepted, (in which case the eclipse is called *total*,) there is another shadow, *r* C D S, distinct from the former, which is called the *penumbra*. Within this, only a part of the sun's rays are intercepted, and the eclipse is called *partial*. If a person could pass, during an eclipse of the sun, from O to D, immediately on emerging from the dark shadow, O *m*, he would see a small part of the sun; and would continually see more and more till he arrived at D, where all shadow would cease, and the whole sun's disk be visible. Appearances would be similar if he went from O to C. Hence the penumbra is less and less dark, (because a less portion of the sun is eclipsed,) in proportion as the spectator is more remote from O, and nearer C or D. Though the penumbra be continually increasing in diameter, according to its length, or the distance of the moon from the earth, still, under the most favorable circumstances, it falls on but about half of the illuminated hemisphere of the earth. Hence, by half the inhabitants on this hemisphere, no eclipse will be seen.

5. Fig. 163 represents an eclipse of the moon. The instant the moon enters the earth's shadow at *x*, it is deprived of the sun's light, and is eclipsed to all in the unilluminated hemi-

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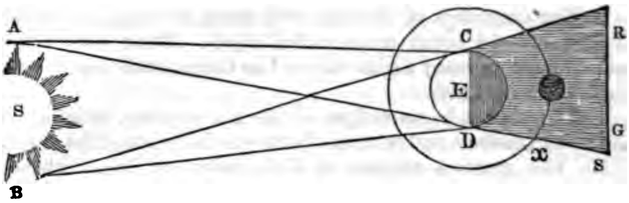
Explain Fig. 162. When is an eclipse called annular? Explain by Fig. 163. What is a penumbra?

sphere of the earth. Hence, eclipses of the moon are visible to at least twice as many inhabitants as those of the sun can be; generally the proportion is much greater. Thus, the inhabitants at a particular place, as Boston, see more eclipses of the moon than of the sun.

Fig. 163.



6. The reason why a *lunar* eclipse is visible to all to whom the moon at the time is visible, and a *solar* one is not so to all to whom the sun at the time is visible, may be seen from the nature of these eclipses. We speak of the sun's being eclipsed; but, properly, it is the earth which is eclipsed. No change takes place in the sun; if there were, it would be seen by all to whom the sun is visible. The sun continues to diffuse its beams as freely and uniformly at such times as at others. But these beams are intercepted, and the earth is eclipsed only where the moon's shadow falls, that is, on only a part of a hemisphere. In eclipses of the moon, that body ceases to receive light from the sun, and, consequently, ceases to reflect it to the earth. The moon undergoes a change in its appearance; and, consequently, this change is visible at the same time to all to whom the moon is visible; that is, to a whole hemisphere of the earth.

7. The earth's shadow (like that of the moon) is encompassed by a penumbra, C R S D, which is faint at the edges towards R and S, but becomes darker towards F and G. The shadow of the earth is but little darker than the region of the penumbra next to it. Hence it is very difficult to determine the exact time when the moon passes from the penumbra into

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Why are eclipses of the moon visible to more inhabitants than those of the sun? Why is a lunar eclipse visible to all to whom the moon is visible at the time? What is said of the earth's shadow? Explain by the figure.

the shadow, and from the shadow into the penumbra; that is, when the eclipse begins and ends. But the beginning and ending of a solar eclipse may be determined almost instantaneously.

8. The diameters of the sun and moon are supposed to be divided into 12 equal parts, called *digits*. These bodies are said to have as many digits eclipsed as there are of those parts involved in darkness.

9. There must be an eclipse of the sun as often, at least, as one of the moon's nodes comes between the sun and the earth.

10. The greatest number of both solar and lunar eclipses that can take place during a year is seven. The usual number is four—two solar and two lunar.

11. A total eclipse of the sun is a very remarkable phenomenon.

12. June 16, 1806, a very remarkable total eclipse took place at Boston. The day was clear, and nothing occurred to prevent accurate observation of this interesting phenomenon. Several stars were visible; the birds were greatly agitated; a gloom spread over the landscape, and an indescribable sensation of fear or dread pervaded the breasts of those who gave themselves up to the simple effects of the phenomenon, without having their attention diverted by efforts of observation. The first gleam of light, contrasted with the previous darkness, seemed like the usual meridian day, and gave indescribable life and joy to the whole creation. A total eclipse of the sun can last but little more than three minutes. An annular eclipse of the sun is still more rare than a total one.

OF TIME.

338. When time is calculated by the sun, it is called solar time, and the year a solar year; but when it is calculated by the stars,[*] it is called sidereal time, and

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[*] The solar year consists of 365 days, 5 hours, 48 minutes, and ~~48~~ 57 sec-

Into what are the diameters of the sun and moon supposed to be divided? How many digits are these bodies said to have eclipsed? How often must there be an eclipse of the sun? What is the greatest number, of both lunar and solar eclipses, that can take place in a year? What is the usual number? What is said of the eclipse of the sun in 1806?

338. What is time called when calculated by the sun? What is sidereal time? How much longer is the sidereal year than the solar?

the year a sidereal year. The sidereal year is 20 minutes and 24 seconds longer than the solar year.

1. A solar year* is measured from the time the earth

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onds; but our common reckoning gives 365 days only to the year. As the difference amounts to nearly a quarter of a day every year, it is usual, every fourth year, to add a day. Every fourth year, the Romans reckoned the 6*th of the calends of March, and the following day as one day;* which, on that account, they called bissextile, or twice the 6th day; whence we derive the name of bissextile for the leap year, in which we give to February, for the same reason, 29 days every fourth year.

* As it may be interesting to those who have access to a celestial globe, to know how to find any particular star or constellation, the following directions are subjoined:

There is always to be seen, on a clear night, a beautiful cluster of seven brilliant stars, which belong to the constellation "*Ursa Major,*" or the Great Bear. Some have supposed that they will aptly represent a plough; others say that they are more like a wagon and horses, the four stars representing the body of the wagon, and the other three the horses. Hence they are called by some the *plough,* and by others they are called *Charles's wain,* or *wagon.*

Fig. 164.

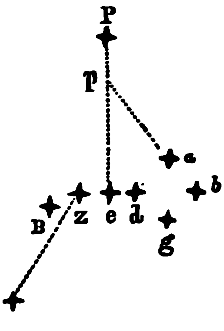


Fig. 164 represents these seven stars: *a b d g* represent the four, and *e z* B the other three stars. Perhaps they may more properly be called a large dipper, of which *e z* B represent the handle. If a line be drawn through the stars *b* and *a,* and carried upwards, it will pass a little to the left, and nearly touch a star represented in the figure by P. This is the polar star, or the north pole star; and the stars *b* and *a,* which appear to point to it, are called the *pointers,* because they appear to point to the polar star.

The polar star shines with a steady and rather dead kind of light. It always appears in the same position; and the north pole of the earth always points to it *at all seasons of the year.* The other stars seem to move round it as a centre. As this star is always in the north, the cardinal points may at any time be found by starlight.

By these stars we can also find any other star or constellation.

How is a solar year measured? What is the length of a solar year? Why is a day added every fourth year, to the year? How is a sidereal year measured?

sets out from a particular point in the ecliptic, as an equinox, or solstice, until it returns to the same point again. A sidereal year is measured by the time that the earth takes in making an entire revolution in its orbit; or, in other words, from the time that the sun takes to return into conjunction with any fixed star.

2. Every equinox occurs at a point, 50″ of a deg. of the great circle, preceding the place of the equinox, 12 months before: and this is called the *precession of the equinoxes.* It is this circumstance which has caused the change in the situation of the constellations of the zodiac, of which mention has already been made.

3. The earth's diurnal motion on an inclined axis, together with its annual revolution in an elliptic orbit, occasions so much complication in its motion, as to produce many irregularities; therefore true equal time cannot be measured by the sun. A clock, which is always perfectly correct, will, in some parts of the year, be before the sun, and, in other parts, after it. There are but four periods in which the sun and a perfect clock will agree: these are the 15th of April, the 16th of June, the 23d of August, and the 24th of December.

4. The greatest difference between true and apparent time amounts to between sixteen and seventeen minutes. Tables of equation are constructed for the purpose of pointing out and correcting these differences between solar time and equal or mean time, the denomination given by astronomers to true time.

Thus, if we conceive a line drawn from the star *z*, leaving B a little to the left, it will pass through the very brilliant star A. By looking on a celestial globe for the star *z*, and supposing the line drawn on the globe, as we conceive it done on the heavens, we shall find the star and its name, which is Arcturus.

Conceiving another line drawn through *g* and *b*, and extended some distance to the right, it will pass just above another very brilliant star. On referring to the globe, we find it to be Capella, or the goat.

In this manner, the student may become acquainted with the appearance of the whole heavens.

What is the precession of the equinoxes? What change has this circumstance caused, with regard to the situation of the constellations? Can true equal time be measured by the sun? Why? At what periods of the year do the sun and a perfect clock agree? What is the greatest difference between true and apparent time?

Many of the foregoing facts, with some others relating to the bodies which compose the Solar System, are arranged in the following Tables. The numbers in these Tables differ, in some respects, from those contained in the body of the work, as they were taken from a different authority.

TABLE I.—*Of the Sun and Primary Planets.*

	Dist. in Millions.	Time of revolving around the Sun.	Time of turning on their Axis.	Diameter in Miles.	The Earth being 1.			Greatest Dist. from the Ecliptic.	Hourly Motion in Miles.	Eccent., Mean Dist. 1.
					Bulk.	Heat & Light.	Density.			
SUN,	* *	* *	24.5 d.	883,217	1,380,000	* *	$\frac{1}{4}$	* *	* *	* *
Mercury,	37	87.98 d.	24. h.	3,123	$\frac{1}{15}$	6.68	2	7° 40′	110,000	0.205
Venus,	68	224.7 "	23.36 "	7,702	$\frac{8}{9}$	1.91	1¼	3° 23′	84,000	0.007
Earth,	93	365.25 "	24. "	7,916	1	1.00	1	0	68,000	0.017
Mars,	144	687.00 "	24.64 "	4,398	$\frac{7}{24}$	.43	$\frac{7}{10}$	1° 50′	54,000	0.093
Vesta,	223	1313.00 "	unknown	unknown	unknown	.18	unknown	7° 9′	45,000	0.097
Juno,	253	1586.00 "	†27. h.	†1,545	†$\frac{1}{135}$	.14	unknown	13°	42,000	0.254
Pallas,	263	1680.00 "	unknown	†2,280	†$\frac{1}{42}$	.13	unknown	34° 30′	41,000	0.246
Ceres,	263	1980.00 "	unknown	†1,761	†$\frac{1}{90}$	.13	unknown	10° 30′	41,000	0.076
Jupiter,	490	4332.60 "	9.94 h.	89,170	1,400	.037	$\frac{23}{100}$	1° 19′	30,000	0.048
Saturn,	900	10759.00 "	10.27 "	79,042	1,000	.011	$\frac{9}{100}$	2° 29′	22,000	0.056
Uranus.	1800	30688.00 "	unknown	35,100	90	.0027	$\frac{1}{5}$	0° 49′	15,000	0.047

† Those figures marked † are not certain

TABLE II.—*Of Secondary Planets.*

OF THE MOON.

Distance from the Earth.	Inclination of Orbit to the Ecliptic.		Revolution around the Earth.		
Miles.	Deg.	Min.	Days.	Hours.	Min.
240,000	5	50	27	7	43

Moon's diameter, 2159. Bulk (that of the earth being 1) 1 — 49.

Period from change to change, 29 days, 12 hours, 44 minutes.

OF THE SATELLITES OF JUPITER.

	Distance from Jupiter.	Inclination of Orbits to the Orbit of Jupiter.			Revolution around Jupiter.		
	Miles.	Deg.	Min.	Sec.	Days.	Hours.	Min.
I	264,490	3	18	38	1	18	27
II	420,815	3	18	00	3	14	58
III	671,234	3	13	58	7	3	42
IV	1,180,582	2	36	00	16	16	32

OF THE SATELLITES OF SATURN.

	Distance from Saturn.	Inclination of Orbits to the Orbit of Saturn.		Revolution around Saturn.		
	Miles.	Deg.	Min.	Days.	Hours.	Min
VII	119,627	30		0	22	37
VI	153,496	30		1	8	53
I	190,044	30		1	21	18
II	243,449	30		2	17	44
III	240,005	30		4	12	25
IV	788,258	30		15	22	41
V	2,297,541	42	45	79	7	54

OF THE SATELLITES OF URANUS.

	Distance from Uranus.	Inclination of Orbits to the Orbit of Uranus.			Revolution around Uranus.		
	Miles.	Deg.	Min.	Sec.	Days.	Hours.	Min.
I	224,155	99 or 80	43 16	53 7	5	21	25
II	290,821	do.			8	16	57
III	339,052	do.			10	23	4
IV	388,718	do.			13	10	56
V	777,481	do.			38	1	48
VI	1,555,872	do.			107	16	42

INDEX.

Aberration of light, 287.
Accelerated Motion, 32.
“ “ how produced, 32.
Accidental Properties of Matter, 19.
Achromatic lenses, 186.
Acid employed in the galvanic circle, 220.
Acoustics, 17, 18, 124.
Acoustic tubes, 130.
Acre of ground, quantity of moisture exuded from in twelve hours, 104.
Action and Reaction, 34.
Action and reaction enable birds to fly, fishes to swim, &c., 36.
Action and reaction of elastic and non-elastic bodies, 36.
Acute Angles, 38.
Advertisement, 7.
Aeriform Fluids, 19, 97, 98.
“ “ elasticity of, 99.
Aerolites, 289.
Africa, pestilential winds from, 109.
Air, 97, 98.
“ a heterogeneous mixture, 98.
“ as a conductor of sound, 127.
“ or atmosphere, at what height it loses its refractive power, 28.
“ circulation of the, 108.
“ compressibility of, 99.
“ compression of the, at the surface of the earth, 28.
“ condensed, experiments with, 117.
“ “ how weighed, 118.
“ contained in water and in wood, 115.
“ decrease of its density, 97.
“ density of, affected by heat and cold, 118.
“ different states of the, at different heights, 98.
“ effect of heat on, 133.
“ effect of its elasticity on a receiver, 109.
“ effect of its elasticity, 101.
“ effects of the rarity of, in very elevated situations, 102.
Air, elasticity of the, opposed to its gravitation, 28.
“ essential to animal life, 122.
“ “ to combustion, 122
“ “ to sound, 124.
“ expansion of, 99.
“ experiment illustrating the compressibility of, 117.
“ experiments showing the elasticity of, 115. 117.
“ experiments showing its fluidity, 119.
“ experiments illustrating the gravity of, 112.
“ experiments showing the inertia of, 119.
“ experiment illustrating the lightness of, 117.
“ experiment illustrating the materiality of, 116.
“ fluidity of the, effect of, 100.
“ heated above the boiling point of water, innocuous, proved by experiments of Sir Joseph Banks, 136.
“ how affected by the vibrations of a sonorous body, 125.
“ how it becomes a mechanical agent, 100.
“ impenetrability of the, 104
“ inertia of, 100.
“ motion of the, how caused, 107.
“ necessary to animal life and to combustion, 98.
“ of what composed, 98.
“ one of the elements of the ancient philosophy, 18.
“ pressure of the, its effects on the liquid form of some bodies, 122.
“ pressure of the, retards ebullition, 122.
“ principal properties of, 98.
“ resistance of the, to the ascent of fluids, 94.
“ resistance of the, to falling bodies, 27.

Air, resistance of the, to the motion of a cannon ball, 44.
" Scales for weighing. 114.
" specific gravity of the, 98.
" " " how affected, 101.
" subject to the law of attraction, 28.
" weight of the, 99.
" or atmosphere, when heaviest, 102.
" why light passing through is partly absorbed, 158.
" when the best conductor of sound, 130.
" where unfit for respiration, 102.
" why invisible, 98.
" why it seems heavier in wet than in dry weather, 102.
" why less dense on an elevated spot, 102.
" why more dense at the surface of the earth, 28.
" Chamber, 117.
" Gun, force of the, 118.
" " principle of the, 118.
" Pump, 109.
" pumps, how made, 109.
" Pump in the steam-engine, 143.
" Pump, experiments made with the, 112.
" Pump, operation of the, 110.
" Pump, "Wightman's Companion" to the, 112.
" Pump, Wightman's Patent Lever, 111.
" Pump, the double, 111.
Alcohol, how inflamed by the Electrical machine, 207.
" how made to appear to boil, 122.
All's Well, (a watchword,) distance at which heard, 130.
Alpha Leonis, 262.
Alphabet of the Magnetic or Electro-Magnetic Telegraph, 252.
Amalgam, 161. 202.
American Electro-Magnetic Telegraph, 251.
Ampère's contrivance for illustrating Electro Magnetic rotation, 246.
Ampere's theory of Electro-Magnetism, 240.
Analysis, or decomposition, 15.
Ancient Philosophers, their opinion of material substances, 18.
Andes, Volcanoes of, distance at which they are heard, 130.
Angle, 37.
" size of, on what it depends, 37.
" of Incidence, 37.
Angles of reflection, 38.
" of vision, 159.
" of vision, its connection with the appearance of the heavenly bodies, 258.
Angles, how measured, 38.
" of incidence and reflection, 39. 128. 141. 157. 165.
" of incidence and reflection always equal, 38.
" right, obtuse, acute, 38.
Animal life, air essential to, 122.
Annular eclipses, 296.
" eclipse of the sun very uncommon, 298.
Anode, 195.
Antarctic Circle, 272.
Aphelion, 265.
Apogee, 266.
Apparatus to illustrate the pressure of fluids, 83.
Apparition, appearance of, presented by concave mirrors, 164.
Aquarius, 263.
Aqueducts, the Roman, 94.
Aqueous humor, 175. 177.
Arabia, pestilential wind from, 109.
Arago, M. his discoveries in Electro-Magnetism, 240.
Archer, The, 263.
Archimedes, 70.
Archimedes' discovery of the mode of ascertaining specific gravity of bodies, 88.
Archimedes, Screw of, 92.
Arctic Circle, 272.
Arcturus, 300.
Aries, 263.
Arm, bones of the, 58.
Art and Science, connection between, 16.
" " difference " 16.
Artesian Wells, 94.
Artificial magnet, 232.
Artificial magnets, how made, 238.
" " new mode of making, 238.
Arts Mechanic, explained, 16.
Ash, specific gravity of, 87.
Asteroids, 257. 279.
Astronomy, 17, 18. 257.
Astronomical Telescope, 184.
Atmosphere, effect of its refractive power, 170.
" effect of its refractive power on the length of the day, 287.
" heaviest in dry weather and lightest in wet, 102.

Atmosphere, height of the, 28.
" instrument for ascertaining the weight of the, 101.
" pressure of the, 99.
" pressure of the, its influence on the barometer, 101.
" pressure of the, on the barometer, on what principle exerted, 102.
" prevents the sky from appearing black, 188.
" weight of the, 99. 112.
Atmospheric pressure in the steam-engine supplanted by the expansive power of steam, 143.
Atmospheric Steam-Engine, 142.
Attraction, 19. 22.
" general law of, 15.
" capillary, 74.
" causes some bodies to rise and others to fall, 29.
" electrical, 199.
" magnetic, 233.
" mutual, 259.
" of cohesion, 23.
" of gravitation, 23.
" of gravitation mutual in all bodies, 26.
" of matter, its connection with Astronomy, 258.
" two kinds of, 23.
" universal, 26.
" where strongest, 74.
" and repulsion of electric currents, 242.
Attractions nicely balanced by creative Wisdom, 259.
Aurora Borealis, 212.
Autumnal equinox, 275.
Axes, 67.
" of the planets, not perpendicular to their orbits, 266.
" of the earth, 271.
Axis of a lens, 171.
" of motion, 41.
Azote, 98.

Bagatelle, 39.
Baker, The Connecticut, 141.
Balance, 57. 263.
Ball, cause of its rebounding, 37
" Hero's. 118.
" thrown from a gun, 39.
" thrown in a horizontal direction, 43.
Ballistic pendulum, 45.
Balloons, cause of their ascending in the atmosphere, 29.
Balloon, the Pneumatic, 115.
Balls, velocity of, when propelled by gunpowder, 45.
Banks, Sir Joseph, his experiments in a heated room, 136.
Barber's (Dr.) Grammar of Elocution, 131.
Bar magnets, how made, 239.
Barometer, 101.
" greatest depression of the 102.
" highest elevation of the, 102
" where highest, where lowest, 102.
" why mercury is used in the, 102.
Base of a body, 47.
Bath, (the Pneumatic Shower,) 120.
Battery, Electrical, 200.
" galvanic, electric currents from the, 240.
Beam of light, 154.
Beech, specific gravity of, 87.
Bell, when loudest in sound, 124.
" when heard most distinctly, 130.
" metal, 69.
Bellows, The Hydrostatic, 82.
Bennett's Gold Leaf Electroscope, improved by Singer, 204.
Beta Scorpii, 262.
Biela's comet, periodical time of, 285.
" prediction of the return of a comet, 285.
Billiards, 39.
Birds, muscular power of, 36.
" how they fly, 36.
Bissextile, 299.
Black, merely a deprivation of color, 190.
" lead, why used in machinery, 69.
Bladder Glass, 113. 115.
" Blowing out" of a steam-engine, 144.
Blue, indigo and violet rays, why least refracted, 187.
" vitriol, 226.
Boats, how propelled by oars, 36.
" &c., why they float in the water, 85.
Bodies floating in a fluid, 85.
" to what they owe their sonorous properties, 125.
" what stand most firmly, 48.
Body of a man, pressure of the atmosphere on, 99.
Boiler of a steam-engine, 143.
" how secured from bursting, 145.

[illegible]
[illegible]
[illegible]
[illegible] Philosophical Apparatus, 5, 44.
[illegible] Air Pump of the, [illegible]
[illegible]
[illegible] sunk in the sea, pressure on, 78.
[illegible] of a pump, 166.
[illegible] specific gravity of, 87.
[illegible] Press, 83.
[illegible] specific gravity of, 87.
[illegible] 22.
Breast water-wheel, 97.
Brewster's, Dr., invention of the Kaleidoscope, 189.
Brewster, his opinion of the cause of meteoric stones, 281.
Bright substances, why heated with difficulty, 137.
Brittleness, 14, 34.
Brydone's calculation of the velocity of a comet, 294.
Buffon's Concave Mirror, 167.
Bulk or size, 2[illegible].
Bull, The, 262.
Buoyancy of salt and of fresh water, 87.
Burning-glass, effect of one made at Leipsic, 173
Burning-glasses, why in the form of a convex lens, 173.
Burning-glasses of concave mirrors. *See Dufay and Buffon*, 167.
" " of concave mirrors, 167.

Caloric or heat, 134.
Calorimotors, 231.
Camera Obscura, 159
" " (portable,) how made, 159.
" " the eye a natural, 175.
Cancer, Tropic of, 272.
" 262.
Cannon ball, 43.
" " utmost velocity of, 45.
Caoutchouc, or India Rubber, cause of its rebounding, 37.
Capella, 300
Capillary, 74
" tubes, 74.
Capricorn, Tropic of, 272.
Capricornus, 263
Capstan, 63
how it differs from a windlass, 63
Carriages, cause of their upsetting, 47.
[illegible] 60.
Cartesian Devil, 116.
Castors, why used on tables, &c., 9.
Cataracts in the eye, mode of removing, 178.
Cat, electricity of the, 215.
[illegible] 185.
Catoptrics, 156.
" fundamental law of, 157.
" facts resulting from the fundamental law of, 165.
Cats, why they require little light, 176.
Celsius' scale for the thermometer, 103.
Central forces, 41.
Centrifugal, 41.
force, 41.
Centripetal, 41.
" force, 41.
Centre of gravity, 40, 41, 49
" " when the same with the centre of magnitude, 48.
" " being supported, the whole body is supported, 46.
" " of a system, 259.
" " of the Solar System, 275.
" " of two bodies connected, 49.
Centre of magnitude, 40, 41.
" of motion, 40, 53, 54.
" of the earth the centre of attraction, 26.
Centres, three different kinds of, 40
Ceres, 257, 279.
" diameter of, 261.
" distance from the sun, 260.
" length of day unknown, 260.
" length of the year of, 260.
" perihelion of, 266.
Chain pump, 92.
Chalk, specific gravity of, 87.
Chantrey, the celebrated sculptor, 137.
Characters used in Almanacs and Astronomical works to represent the planets, and also the signs of the Zodiac, 263.
Charged, when a body is said to be, with electricity, 197.
Charles' Wain, 299.
Chemical action, general law of, 221.
" effects of light, 191.
" properties of liquids and fluids, 98.
Chemistry, 14, 15, 17.
" and Natural Philosophy, difference between, 15.

Chemistry, science of, 98.
Chisels, 67.
Chord, (musical,) how obtained, 126.
" of an octave, a fifth, &c., how obtained, 126.
Choroid, 175.
Chromatics, 186.
Circle and its parts, 37.
" centre of, 37.
" of perpetual occultation, 288.
" " apparition, 288.
Circuit of electricity, 201.
Circular motion, 40.
" " how changed to rectilinear, 64.
" " of the revolving jet, by what caused, 118.
Circumference, 37.
Cistern of a steam-engine, 143.
Clapper of a pair of bellows, 106.
Clay, contraction of by heat, 138.
Climate, cause of the variety of, 270.
Clock, hour and minute hands of, 53.
Clocks, how regulated, i. e. to go faster or slower, 52.
" pendulums of, how kept in motion, 51.
" pendulums how lengthened or shortened, 52.
" time of, sometimes before, and sometimes after that of the sun, 300.
" why affected by the seasons, 53.
Clothing, warmth of different kinds of, cause of, 135.
Clouds, height of the, 28.
" of what composed, 28. 104. 133.
Clydesdale, effect of galvanism on, 228.
Coal, specific gravity of, 87.
Cobalt possessed of magnetic properties, 232.
Cogs on wheels, 65.
Cohesion, attraction of, 23.
Cohesive attraction, aeriform fluids destitute of, 98.
" " affected by heat, 133.
" " independent of gravitation, 26.
" " not found in fluids, 99.
Coins of alloyed metals, why they perish, 230.
" of pure metal, why more imperishable than those which are alloyed, 230.
Cold, 139. 132.
" and heat, effect of, on density, 140.
Cold, measure of, 138.
" severity of, how we are shielded from, 142.
" weather, when the earth is nearest the sun, 270.
Collision, apparatus for illustrating, 38.
Color, an accidental property, 18. 188.
" brightness and intensity of, on what dependent, 190.
" cannot exist without light, 190.
" change of, in bodies, by what caused, 190.
" deepness of, on what it depends, 190.
" of bodies, on what dependent, 189.
Colors, different refrangibility of the, in a ray of light, 187.
" dispersion of, by lenses, 184.
" of bodies, 189.
" the seven reduced to four, 188.
Combustible substances, 166.
Combustion, air essential to, 162.
" does not destroy the simple substances of which a body is composed, 22.
Comet, 262.
" Brydone's calculation of the velocity of, 264.
" Pope Calixtus' anathema of a, 265.
" (Halley's,) periodical time of, 285.
" return of a, first predicted, 265.
" tail of a, 262.
Comets, 257.
" appear to have little attractive force, 266.
" density of, 265.
" disturbed by the gravitation of the planets, 265.
" immense velocity of when in perihelion, 254.
" length of the tails of, 265
Comets, motion of tails of, 264.
" Newton's opinion respecting the tails of, 264.
" number of, 263.
" " in the Solar System, 285.
" orbits of which have been calculated, 284.
" periodical time of Halley's, Encke's, and Biela's, 285.
" revolution of, 284.
Common Pump, 92.
" air, specific gravity of, 87.
Compass needles, how corrected, 226.

Compass, why furnished with two sets of [illegible]. [illegible]
Compass, when worn. 34.
Compound battery of great power. 228.
" galvanic circles. 222.
" lever. 37.
" motion. 38.
Compressibility. [illegible] 38.
" of air, experiment illustrating the. 117.
Compression, all substances susceptible of. 38.
" heat produced by. 137.
Conchology. 13, 14.
Condensation. 37.
" of air. 112.
Condensed, meaning of the term. 37.
" air, how weighed. 118.
Condenser of a steam-engine. 143.
" of the steam-engine, by whom invented. 145.
Condensing syringe. 112.
" and Exhausting syringe. 117.
" steam-engines. 145.
Conductors of electricity. 196.
" " list of. 195.
" imperfect, of electricity, list of. 197.
Concave glasses, when to be used in spectacles. 173.
" " why used in spectacles. 174.
" lens, single. 171.
" " double. 171.
" lenses diminish objects. 172.
" mirror, Dufay's. 167.
" " objects reflected from. 164.
Concave mirrors. 162.
" " appearance of apparitions produced by. 164.
" " effects of. 164.
" " facts with regard to. 166.
" " images reflected by, when upright and when inverted. 165.
" " peculiar property of. 164.
" " true focus of a. 163.
" " used as burning-glasses. 167.
" surfaces collect sound. 130.
" " facts with regard to. 174.
Cone. 40.
Conjunction, superior and inferior. 265.
Connecticut River. 141.
Conservatory of Arts and Trades, walls of, how restored to a perpendicular position. 138.
Constellation, what is meant by a heavenly body being in a particular. 265
Constellations. 261.
" how to find with a globe, 290.
" in which the sun and the earth relatively appear, 263.
" near the South pole but little known. 257.
" number of. 257.
" of the Zodiac, cause of the change in. 300.
" of the Zodiac have lost their original names, 263.
" of the Zodiac, representation of the position of the. 273.
Contents, Table of. 11.
Convergency of the scales in a balance, 57.
Converging rays. 153.
" " effect of on concave surfaces. 174.
" " reflected from a concave surface. 166.
" " reflected from a convex surface. 166.
" " when unrefracted. 173.
Convex glasses, when to be used in spectacles. 174.
" " why used in spectacles. 174.
" lens, (single,) 171.
" " " focal distance of a. 172.
" " (double,) 171.
" " effect of on the eye. 173.
" lenses magnify objects. 172.
" " why they operate as burning-glasses. 173.
" " rays perpendicular to a, 172.
" mirrors. 161.
" " convert parallel to divergent rays and make divergent still more divergent. 163.
" " facts with regard to. 165.
" " reflect convergent rays

either parallel or less convergent, 163.
Convex mirrors reflect images smaller than the objects, 163.
" surfaces disperse sound, 130.
" " facts with regard to, 173.
Cork, 237.
" specific gravity of, 87.
" why it will not sink in water, 29. 85.
Cornea, 175, 176.
Cooper's mode of securing hoops, 138.
Copper, specific gravity of, 87. ....
Couching (of the eye,) 179.
Coulomb's discovery that all solid bodies are susceptible of magnetic influence, 234.
" Couronne des tasses," 224
Crab, The, 263.
Cranks, 64.
Cross, the Southern, 288.
Cross-currents, 91.
Crystalline humor, effect of when too round or too flat, 179.
" humor, convexity of, how increased or diminished, 179.
" lens, 175. 177.
Current of electricity, 221.
" rapidity of, how ascertained, 91.
Currents of electricity, 240.
Curvilinear motion, 42.
Cutting instruments, 67.
Cylinder, 62.
" how made to roll up a slope, 48.
" of a steam-engine, 143.
Cyprias, 129.

Daguerre, M., 193.
Daguerreotype, 193.
Dark, why none but luminous objects can be seen in the, 158.
Darkness produced by a total eclipse of the sun, 155.
Davis, (Daniel, Jun.,) 237.
Davis, (Daniel. Jun.,) his treatise on magnetism, 237. 247. 251. 255.
Davy, Sir Humphrey, his discoveries in Electro-Magnetism, 240.
Day of a planet, 260.
Day Glass, 184.
Day and night, cause of, 273.
Days, length of the, cause of, 274.
Days and nights, cause of the difference of the length of, 266.
Dedication, 4.
Deepness of color, on what dependent, 190.
Degrees, 37.
Delisle's scale for the thermometer, 102.
Delphi, Oracle of, 132.
Dense bodies, 23.
Density, 19. 23.
" bodies of different, why they fall with unequal velocity, 27.
" how affected by heat and cold, 140.
Depth, 21.
" of a well, estimated by a falling body, 33.
Descent of falling bodies, how impeded, 30.
" of projectiles, 42.
Devil, the Cartesian, 116.
Dew, how produced, 104.
Dew and Fog, difference between, 104.
Diagonal, 38.
Diameter, 37.
" of Heavenly bodies, how expressed, 161.
Diameters of the sun and moon, how divided with reference to eclipses, 298.
Difference between Fog and Dew, 104.
" between Natural Philosophy and Chemistry, 15.
Digits, 298.
Dilatation of metallic beams effected by the weather, 139.
Dionysius, the tyrant of Sicily, 128.
" ear of, 128.
Dioptrics, 167.
" fundamental laws of, 168.
" principles of, 174.
Dipping of a magnetic needle, 236.
" of the magnetic needle, cause of the, 236.
" of the magnetic needle, how corrected, 236.
Direction, line of, 47.
Discord, (musical,) how produced, 126.
Dispersion of colors by lenses, 184.
Distance, mean, of the several planets from the sun, 260.
Distilled water, a standard for computing specific gravity, 86.
" " why used for computing specific gravity of bodies, 86.
Distinction between the signs and the constellations of the zodiac, 263.
Diverging rays, 153.
" " effect of concave surfaces on, 174.
" " effect of convex surfaces on, 172.

Diverging rays, reflected from a concave surface, 166.
" " reflected from a convex surface, 166.
Diving Bell, 104.
" " forcing pump attached to the, and why, 105.
" " how supplied with air, 105.
" " its uses, 105.
" " principle of the, 104.
Divisibility, 19. 21.
Double action of the Steam-engine, 142.
" Air Pump, 111.
" concave lens, 171.
" convex lens, 171.
" microscope, 180.
Downward pressure of fluids, by what caused, 81.
Drake, Sir Francis, 237.
Drawing, Perspective, on what depends, 188.
Drop, (the Guinea and Feather,) 110.
Ducks, guns suitable for, 46.
Ductility, 19. 23.
Dufay's large concave mirror, 167.
Dungeon, called the Ear of Dionysius, 128.
Duration of a total eclipse of the sun, 296.

Ear of Dionysius, 128.
Earth, 257. 278.
" a magnet, 237.
" an oblate spheroid, 278.
" apparent size of, when viewed from the moon, 279.
" attracts the heavenly bodies, 259.
" axis of the, 271.
" circumference of the, 257.
" diameter of the, 257. 261.
" difference of its equatorial and polar diameters, 278.
" distance from the sun, 260.
" distance of moon from the, 278.
" effect of the inclination of its axis, 271.
" how known to be round, 257.
" length of the year of, 260.
" length of day, 260.
" moon of the, 258.
" one of the elements of the ancient philosophy, 18.
" perihelion of, 266.
" phases of the, when viewed from the moon, 278.
" proximity of, to the sun in winter, 266.
" revolution of, 42.
Earth, situation of the, [illegible]
" size of, compared [illegible] falling bodies, [illegible]
" the principal [illegible] gravity, 19[illegible]
" when nearest to the sun, [illegible]
East wind, how produced, [illegible]
" winds prevalent at the equator, why, [illegible]
Ebullition, meaning of the term, [illegible]
" retarded by pressure of the air, [illegible]
Echo, how produced, [illegible]
Eclipse, a total of the sun, very uncommon, 296.
", of the moon, 294.
" of the sun, 294.
" of the sun, total, duration of, 296.
" (total) of the sun, darkness produced by, [illegible]
Eclipses, 294.
" annular, 296.
" explanation of the causes of, 295.
" how measured, 295.
" length of, 295.
" when they take place, [illegible]
Ecliptic, 262. 272.
" and Zodiac, difference between, 272.
Edifice, what kind of, the strongest, 48.
Eduction Pipe, 143.
Effect of the voltaic pile on animal life, 230.
Egypt, lands of, how formerly drained, 93.
Elastic fluids, 98.
Elasticity, 19. 24. 98.
" of air and of aeriform fluids, 99.
" " " experiments illustrating, 115. 117.
" " " shown by means of the Air-pump, 112.
" the cause of the sonorous properties of bodies, 125.
Electric currents, attraction and repulsion of, 242.
" current, direction of the, may be ascertained, 242.
" currents, how excited in a conductor, 253.
" shock, 199. 205.
" currents, peculiar action of, 243.
" fluid, how communicated, 196.
" " in thunder-storms, 215.

Electric fluid, immense velocity of the, 215.
" shock from galvanic battery, how received, 224.
Electrical attraction and repulsion, 199.
" Battery, 200.
" bells, 206. 208.
" fishes, 216.
" machine, 201.
" " experiments with the, 204.
" " operation of the, 203.
" machines, on what principle constructed, 202.
" " power of, how tested, 204.
" Sportsman, 209.
" Sawmill, 213.
" Tellurium, 206.
Electricity, 17, 18. 194.
" and magnetism, combined action of, 241.
" by induction, 201. 213.
" by transfer, 201.
" circuit of, 201.
" currents of, 240.
" developed by chemical action, 220.
" developed by heat, 255.
" different kinds of, always accompany each other, 198.
" effects of, 194.
" effect of, on the Magnetic Needle, 241.
" excited in glass, what called; 198.
" experiments in, 210.
" Frictional, and Galvanic, or Voltaic, 196.
" General remarks on, 212.
" how excited, 195.
" how it divides all substances, 195.
" induced by magnetism, 241.
" magnetism induced by, 241.
" particular law of, 15.
" (galvanic,) perfect and imperfect conductors of, 219.
" positive and negative, 195.
" positive and negative merely relative terms, 215.
" principal reservoir of, 197.
" simplest mode of exciting, 198.
" three states of, 256.
" velocity of, 252
Electrics, 194.
Electrified positively, 195.
Electrodes, 195.
Electro-Magnet, 248.
" " formed by Professor Henry and Dr. Ten Eyck, 249.
" " of Professor Henry, the means of the construction of the Magnetic Telegraph, 251.
Electro-Magnetic induction, 243.
" " Multiplier, 244.
" " rotation, 244. 246.
" " rotation, Ampère's apparatus for illustrating, 246.
" " rotation, Faraday's apparatus for illustrating, 245.
" " Telegraph, 251.
Electro-Magnetism, 17, 18. 196. 232. 240.
" " as a moving power, 253.
" " principal facts in connexion with, 241.
" " wonders of, 252.
Electrometer, 204.
Electroscope, 204. 244.
Electrotype copy of a steel plate, 150.
Elm, specific gravity of, 87.
Encke's comet, periodical time of, 285.
" prediction of the return of a comet, 285.
Engineer, how taught to direct his guns, 46.
Engines, Steam, the Condensing and the Non-condensing; or the high and the low pressure, 145.
Entomology, 13, 14.
Ephesus, oracle at, 132
Equation of time, tables of, 300.
Equator, 271.
Equatorial regions move fastest in the daily revolution of the earth, 42.
" " why hottest, 270
Equilibrium, how produced in the Steelyard, 57.
" of fluids, 76.
" " " how applied to tho common pump, 106.
" " " instrument for showing, 95.
" " " result of the, 100

Equilibrium of fluids, the principle of the barometer, 102.
Equinoxes, 275. 300.
" precession of the, 263. 300.
Essential elements of a galvanic circle, 220.
" properties of matter, 19.
Ether, how inflamed by the electrical machine, 207.
" how made to appear to boil, 122.
Ethics, meaning of, 13.
Evaporation of water, 22.
Exhausting and Condensing Syringe, 117.
Exhaustion by an air-pump, degree of, how shown, 111.
Expansibility, 19. 24.
Expansion caused by heat different in all substances except aeriform fluids, 140.
" of bodies by heat, instrument to show, 138.
Expansive power of Steam, substituted for atmospheric pressure in the Steam-engine, 143.
Experiment illustrating at once the materiality, compressibility, elasticity, and lightness of air, 116.
" illustrating the principal truths of Hydrostatics and Pneumatics, 117.
" showing that the pressure of a liquid is exerted in all directions, 117.
" showing that the pressure of a liquid is in proportion to its depth, 117.
" showing that the pressure of the air retards evaporation, 122.
" to freeze water artificially, 123.
Experiments (miscellaneous) depending on two or more properties of air, 120.
" illustrating the gravity of air, 112.
" illustrating Divisibility, 21.
" illustrating the impenetrability of water and of air, 20.
" in electricity, 210.
" showing mutual action and reaction, 35.
" showing the elasticity of air, 115.
Experiments showing the fluidity of air, 119.
" showing the inertia of air, 119.
" to show that heat is produced by compression, &c., 138.
" with condensed air, 117.
" with full and empty bottles sunk in the sea, 73.
" with the electrical machine, 204.
" with the magnet, 239.
" with the Siphon, 121.
Extension, 19, 21.
Eye, a natural Camera Obscura, 178.
" brilliancy of the, by what caused, 176.
" color of the, cause of, 175.
" remedy for the defects of the, 174.
" explanation of the, 175.
" imperfections of the, 179.
" of what composed, 175.
" parts of, described, 178.
" the human, glasses suitable for, when too round or too flat, 175.
" what defects of are remedied by the use of spectacles, 179.
" why affected by sudden changes in the degree of light, 176.
Eyes, difference produced by using both, 179.
" distinct images formed on each, and why, 179.

Facts explained by galvanism, 230.
Fahrenheit's scale for the thermometer, 103.
Falling bodies, law of, 27.
" of bodies, by what caused, 25.
Falls of Niagara, 189.
Faraday's apparatus to illustrate electro-magnetic rotation, 245.
" discovery of the electrical powers of a magnet, 240.
" nomenclature of electricity, 195.
Figure, 19. 21.
Fir, specific gravity of, 87.
Fire, one of the four elements of the ancient philosophy, 18.
Fire-box of a Locomotive Steam-engine, 148.
Fire-engines, on what principle constructed, 107.
Firing at a bird on the wing, 50.
" at a vessel in motion, 50.

Fishes, electrical, 216.
  " how enabled to rise and to sink in water, 36.
  " how they swim, 36.
  " the, 263.
Fixed Stars, 258.
Flap of an electrical machine, 203.
Flavio de Melfi, 237.
Flavio Gioia. *See Flavio de Melfi*, 237.
Florence, experiment at, to illustrate the impenetrability of water, 20.
Fluid, a, 73.
  " an aeriform, 97.
  " aeriform explained, 19.
  " form of bodies, cause of, 74.
  " pressure of a, in proportion to its height, 82.
Fluidity of Air, experiments showing the, 119.
  " of air shown by means of the Air-pump, 112.
  " the consequence of independent gravitation, 100.
Fluids communicate pressure, 83.
  " as conductors of sound, 127.
  " discharged more rapidly by means of pipes, 91.
  " discharged with greater rapidity when warm, 91.
  " downward, upward, and lateral pressure of, how shown, 78.
  " elastic, 98.
  " floating on other fluids, 85.
  " gravitation of the particles of, 74.
  " immense pressure they are capable of exerting, 83.
  " lateral pressure of, to what proportioned, 80.
  " level or equilibrium of, 76.
  " particles of, how arranged, 77.
  " particles of, their peculiar gravitation, 77.
  " particles of, when at rest, 78.
  " preserve their own equilibrium, 76.
  " pressure of, 77.
  " pressure of, dependent solely on depth, or the height of the column above, 80.
  " pressure of, in what direction exerted, 78.
  " pressure of, to what proportioned, 78.
  " prone to expansion, 74.
  " subject to the same laws as liquids, 98.
  " subjected to a peculiar kind of attraction, 74.
Fluids, surface of, always spherical, 78.
  " transfer of, from one vessel to another, 121.
  " upward, downward, and lateral pressure of, by what caused, 81.
  " when discharged with greatest velocity, 90.
  " why they cannot be formed into figures, 74.
Flying, effected by action and reaction, 36.
Fly-wheels, 60.
Focal distance of a lens, 172.
Focus, imaginary, 162.
  " of a concave mirror, 163.
  " of rays of light, 153.
  " of sound, 129.
Fog and dew, difference between, 104.
  " how produced, 104.
  " why it gives a red appearance to the Sun, 187.
Force, 30.
  " centrifugal, 41.
  " centripetal, 41.
  " of projection, 40.
Forces, central, 41.
  " operation of equal and unequal, at different angles, 40.
  " which impede a moving body, 22.
Forcing Pump, 92. 107.
  " " attached to the diving-bell, 105.
Fountain, Artificial, simple mode of making, 94.
  " Hero's, 118.
  " Glass and Jet, 114.
Fountains, 22.
  " how formed, 94.
Fracture of glass chimneys of lamps, how prevented, 139.
Franklin, (Dr.,) inventor of Lightning-rods, 216.
Franklin, (Sir John,) 237.
Free heat, 134.
Friction, 69.
  " allowance made for, in calculating the power of a machine, 69.
  " by what caused, 69.
  " kinds of, 69.
  " how diminished, 69.
  " how it increases, 69.
  " the rolling, 69.
  " the sliding, 69.
  " wheels and rollers, 69.
Frictional Electricity, 196.

[illegible]

Gravity. [illegible]
- [illegible]
- [illegible] in the human body, [illegible]
- [illegible]
- how all substances are affected by, [illegible]
- of air, experiments illustrating the, [illegible]
- of air shown by means of the air-pump, [illegible]

Gravity, specific, 29.
" where most powerful, 26.
Great Bear, 299.
Grouse, guns suitable for, 46.
Grove's Battery, 227.
Guinea and Feather Drop, 119.
Gun, (the Air,) force of the, 118.
" " principle of the, 118.
" where it produces little noise, 124.
Gunnery, science of, 45.
Gunpowder, force of, 45.
Guns, long and short, comparative advantage of, 46.
" for sporting, length of, 46.
Gymnotus Electricus, 216.

Hail, 22.
" and snow, how they differ from rain, 86.
" how formed, 86. 104.
Hair-spring of a watch, 53.
Halley's (Dr.) prediction of the return of a comet, 285.
Hand-glass, 113.
Handles of tea and coffee pots, why made of wood, 137.
Harding, Mr., his discovery of the planet Juno, 279.
Hare, (Dr.) inventor of the Calorimotor, 231.
Harmattan, 109.
Harmony, science of, on what founded, 126.
Harvest Moon, 292.
Hatchets, 67.
Hearing-trumpets, 129.
Heat absorbed by dark bodies, 137.
" at the focus of a convex lens, 173.
" best conductors of, 136.
" and cold, their effect on density, 140.
" and cold, as relative terms, 134.
" cause of the fluid form of bodies, 74.
" conducted with greater facility by some substances than by others, 135.
" conducting power of, in different substances, 136.
" conduction of, 136.
" effect of on air, 133.
" effects of on the particles of fluids, 91.
" effect of on the particles of some kinds of substances, 133.
" effect of on water, 133.
Heat, electricity developed by, 255.
" exception to expansive force of, 135.
" free and latent, 134.
" high degrees of, how measured, 138.
" how propagated, 136.
" how reflected from bright or polished surfaces, 141.
" imponderable, 132.
" its effect on metals, 86.
" its nature unknown, 132.
" its tendency to equal diffusion, 135.
" laws of, 132.
" measure of, 101. 103.
" most obvious effect of, 138.
" of summer, cause of, 269.
" of the sun, effect of the, on the earth's surface, 103.
" operates in opposition to gravity and cohesion, 99.
" or caloric, 134.
" passage of, irresistible, 133.
" principal effects of, 134.
" produced by compression, 137.
" radiation of, 136.
" reflected, 137.
" retained longest by those bodies which take the longest time to acquire it, 141.
" sources of, 135.
" when the greatest on the earth's surface, 270.
" why apparently unequal in bodies of the same temperature, 135.
Heated room, Sir Joseph Banks' experiments in, 136.
Heavenly bodies attract the earth, 259.
" " diameter of, how expressed, 161.
" " motion of the, 266.
" " motion of, why invisible, 161.
" " never seen in their true position, 169. 287.
" " obedient to the laws of motion, 259.
" " situation of, calculated from the centre of the earth, 288.
" " when unaffected by refraction, 169.
Heavens, appearance of the, how to become acquainted with, 300.
" why they appear bright in the daytime, 170.

Heaviness or weight of bodies, by what caused. 25.
Heavy bodies, 29.
  " " how made to float in the air. 22.
Height, 21.
  " of a building estimated by a falling body. 33.
  " of mountains ascertained by the barometer, 102.
Heliacal Ring, 248.
Heliography, 193.
Helix, 244. 247.
  " on a stand, 247, 248.
Hemispheres, the Magdeburgh, 112.
  " (Otto Guericke's,) kept together by the pressure of the air, against the force of thirty horses, 113.
Henry, (Prof.) his first application of Electro-magnetism as a moving power, 253.
Henry, (Prof.) powerful electro-magnet formed by, 249.
Hero's Fountain, 118.
  " Ball, 118.
Herschel, (or Uranus,) 281, 282.
  " diameter of, 261.
  " distance from the sun, 260.
  " length of day unknown, 260.
  " length of the year of, 260.
  " perihelion of, 266.
  " (Dr.) number of stars seen by in a quarter of an hour, 286,
  " Sir J., his illustration of the comparative size and distance of the heavenly bodies, 261.
  " Sir J., his calculation of the distance of the stars, 286.
  " Sir John's opinion of the height of the atmosphere, 28.
  " Sir J. W. F.'s treatise on astronomy, 262.
Hesperus, 277.
Heterogeneous, 19.
Hiero, King of Syracuse, 70.
High-pressure Steam-engine, 145.
High tones of musical instruments, how caused, 125.
Homogeneous, 19.
Hoops, how secured on casks, &c., 138.
"Horse Power," meaning of the term as applied to the steam-engine, 145.
Horses, how made to draw unequal portions of a load, 58.
Horse-shoe Magnet, 235.
  " " how to be kept. 239.
Horse-shoe Magnets, how made, 239.
Human Voice, Dr. Rush's work on the Philosophy of the. 131.
  " " imitative power of the, 131.
  " " sound of the, how produced, 130.
Humor, the aqueous and the vitreous, 175.
Humors of the eye, 175.
  " " shape of the, 177.
Hunter's moon, 292.
Hurricanes, how produced, 108.
Hydraulics, 17, 18. 73. 90.
Hydro-electric current, 255.
Hydrogen, a constituent part of water, 19.
  " Gas, convenient mode of procuring, 209.
  " " specific gravity of, 87.
  " Pistol, 209.
  " " how used with the thunder-house, 211.
Hydrometer, 89.
Hydrostatic Bellows, 82.
  " paradox, 81.
  " press, 84.
Hydrostatics, 17, 18. 73.
  " principal truths of, by what experiment illustrated, 117.
Hygrometer, 101. 103.

Ice, 74.
  " consequence of the specific gravity of, 140.
  " specific gravity of, 87.
  " why it floats in water, 140.
  " why wrapped in woollen cloths in summer, 136.
  " and snow more easily melted under a dark covering, 137.
Ichthyology, 13, 14.
Identity of common, voltaic, magnetic, thermo and animal electricity, 240.
Image inverted, how produced, 159.
  " of objects reflected from convex mirrors smaller than the object, 163.
  " seen through telescopes of different kinds, 183.
  " when inverted, 162.

Images inverted on the retina of the eye, why seen erect, 179.
Imaginary focus, 162.
Impenetrability, 19.
" of the air, 104.
" of air and of water, experiments illustrating, 20.
" possessed by fluids, 99.
Imperfect conductors of electricity, 219.
Incidence and reflection, angles of, 157.
" angle of, 37. 128.
Incident and reflected, 36.
" motion, 36.
Inclination of the earth's axis, important consequences of, 271.
Inclined Plane, 54. 66.
" " application of the, 67.
" " advantage gained by the use of the, 66, 67.
Incombustible substances, 138.
Indestructibility, 19. 21.
India rubber, 24.
" " Glass, 113. 115.
Inertia, 19. 22. 30.
Inertia of Air, experiments showing, 119.
" " shown by means of the Air-pump, 112.
Inferior Conjunction, 265.
" Planets, 260.
Instruments for raising water, 92.
" on what principle constructed, 54.
" wind and stringed, sound of, how affected, 126.
Insulated, (in electricity,) 197. 205.
Intellectual Philosophy, 13.
Intensity of electricity from a galvanic battery, 228.
" of chemical agency in galvanism, how increased, 230.
Introduction, 13.
Invisible, when an object becomes, 160.
Iris, 175, 176.
Iron, 70.
" how made magnetic, 238.
" specific gravity of, 87.
" tenacity of, 25.
Ivory, elasticity of, 24.

Jacket, in the Steam-engine, 146.
Jeffrey, Mr., 145.
Jet, the straight and revolving, 118.
Joint, the toggle, or knee, 73.
Jointed Discharger, 200.
Juno, 257. 279.
" diameter of, 261.
Juno, distance from the sun, 260.
" length of day, 260.
" length of the year of, 260.
" perihelion of, 266.
Jupiter, 257.
" and Saturn, disturbances of their motions, 283.
" diameter of, 261.
" distance and size of his moons, 280.
" distance from the sun, 260.
" eclipses of the satellites of, and their use, 280.
" heat and light of, 280.
" length of day, 260.
" length of the year of, 260.
" moons of, 258, 280.
" perihelion of, 266.
" satellites of. *See Table* 21, page 302.
" the largest of the planets, 260.
" why no change of the seasons in, 280.
Jupiter's belts, 281.

Kaleidoscope, 191.
Keeper of a magnet, 235.
Kepler's law, 267.
King's (Dr.) Lightning-rods, 214.
Knee-joint, (in mechanics.) 73.
Knives, 67.
Knob of an Electrical battery, 200.

Ladder, 58.
Lamps, glass chimneys of, how preserved from fracture, 139.
" wicks of should be often renewed, and why, 75.
" why they sometimes fail to give light, 75.
Lantern, the magic, 182.
La Perouse, 237.
Latent heat, 134.
Lateral pressure of fluids, to what proportioned, 80.
Lathes, 63.
Law of falling bodies, 33.
Laws of Natural Science, general and particular, foundation of, 15.
Lead, specific gravity of, 87.
Leaden hemispheres to show cohesive attraction, 23.
Leap-year, 299.
Leaves of an axle, 65.
Length, 21.

[illegible] the different sights, manner of
  its difference [illegible], 286.
Lens, 172.
  " [illegible], 77.
  " double concave and double con-
    vex, 77.
  " double convex, used by Mr. Park-
    er, effect of, 172.
  " focal distance of, 172.
  " how made use of to magnify ob-
    jects, 182.
  " single concave, 77.
  " " convex, 77.
  " the Crystalline, 172.
  " to estimate the effects of, 172.
Lenses, achromatic, 184.
  " effect of various forms of, 77.
  " image in double convex, focal
    distance of, 172.
  " various kinds of, 77.
  " which have the greatest magni-
    fying power, 180.
  " which have the shortest focus,
    180.
  " why made small, 180.
Leo, 302.
Level, or equilibrium of fluids, 76.
Lever, 54.
  " an appendage to the screw, 65.
  " applied to hydrostatic pressure
    in Bramah's Press, 84.
  " different kinds of, 54.
  " examples, 57.
  " mechanical advantage of the, 55.
  " of the first kind, instances of,
    57.
  " of the second kind, 57.
  " of the third kind, 58.
[illegible] Dr., Winslow, [illegible].
Leyden Jar, 198.
  " " how charged either posi-
    tively or negatively, 205.
  " jars charged from the clouds
    by Franklin, 216.
Libra, 302.
Light, aberration of, 287.
  " absorption of by the atmosphere,
    288.
  " absorbed by all bodies, 277.
  " always of the same nature, 280.
  " bodies, 24.
  " cannot exist without matter, 280.
  " chemical effects of, 18, 288, 21,
    289.
  " colors which enter into the com-
    position of, 156.
  " how projected, 154.
Light, intensity of diminished by reflec-
    tion, 157.
  " [illegible] effects of, 181.
  " of what composed, 156.
  " passing from one medium to an-
    other, 168.
  " passing through different medi-
    ums, 170.
  " refraction of through a prism, 157.
  " reflected, fundamental law of
    157.
  " reflected, laws of, 158.
  " Sir Isaac Newton's opinion of,
    182.
  " Thermal effects of, 288.
  " time occupied by, in its passage
    from the sun to the earth, 181,
    288.
  " various theories concerning its
    nature, 182.
  " velocity of, 186.
  " what portion of useful in vision,
    177.
  " when said to be reflected, 156.
  " why some animals require but
    little, 176.
  " zodiacal, 278.
Lightning, 212.
  " and electricity, identity of
    proved, 216.
  " rods, 217.
  " " extent of the security
    of, 218.
  " " should not be painted,
    218.
  " " security of shown by
    the thunder-house,
    221.
  " " square better than
    round ones, 218.
Line of direction, 67.
Linen, why it readily absorbs moisture,
    72.
  " garments, why cool, 126.
Lion, The, 302.
Liquid, how it differs from a fluid, 73.
  " form of bodies partly dependent
    on the pressure of the air, 122.
Liquids have little elasticity, 24.
  " press according to height, appa-
    ratus to illustrate, 53.
List of works consulted in the prepara-
    tion of this volume, 5.
[illegible], 12.
Living men, specific gravity of, 87.
Loadstone, 222.
Locomotive Steam-engine, 148.

Locomotive Steam-engine, internal section of Hinkley and Drury's, 149.
" Steam engine, operation of the described, 148.
Logy, its meaning as an affix, 13.
Longitude determined by eclipses of the satellites of Jupiter, 280.
Loss of weight in bodies immersed in water, 88.
Low-pressure Steam-engine, 145.
Low tones of musical instruments, from what they proceed, 125.
Lucifer, 277.
Luminous bodies, 152.
" " how seen, 157.
Lunar eclipses, 294–297.
Lungs, state of the, how ascertained by physicians, 127.

Machine, force of a, communicated to another at a distance, 84.
Machines, power of, how limited, 70.
" on what principles constructed, 54.
Magazine, magnetic, 239.
Magdeburgh cups, or hemispheres, 112.
Magic Lantern, 182.
Magnet, attraction of the, 234.
" attractive power of the, where strongest, 233.
" being broken, each part becomes a perfect magnet, 235.
" communication of the properties of a, 234.
" different poles of attract, and similar repel each other, 234.
" dipping of a, 236.
" electrical properties of the, 233.
" electricity induced by a, 241.
" experiments with the, 239.
" how supported, 233.
" permanent, 232.
" powerful one formed by Prof. Henry and Dr. Ten Eyck, 249.
" polarity of the, 233.
" polarity of the, analogous to the forms of electricity, 234.
" poles of a, and where situated, 233.
" position of a, in reference to the electric current, 242.
" power of destroyed or weakened by heat, 236.
" power of, increased by action, and impaired or lost by disuse, 234.
Magnet, properties of the, 232.
" properties of, how acquired by soft iron, 232.
" the U, or Horse-shoe, 235.
" variation of the, 236.
Magnetic attraction of iron, &c., how prodigiously increased, 241.
" magazine, 239.
" needle, variation of the, does not impair its utility, 238.
" needle, variation of the, long misunderstood, 236.
" needles, how made, 239.
" north pole of, most powerful in north, and south pole in south latitude, 238.
" pole, revolution of a, 244.
" poles, 233.
" " the earth has four, 237.
" " where strongest, 237.
" power of the Magneto-Electric machine, when the greatest, 255.
" power resides on the surface, and independent of the mass, 235.
" power readily acquired by soft iron, and with difficulty by hard iron or steel, 235.
" substances, 234.
" Telegraph. *See Electro-Magnetic Telegraph*, 251.
" Telegraph, Alphabet of the, 252.
" Telegraph, Battery used for the, 227.
Magnetism, 17, 18, 232.
" and Electricity, combined action of, 241.
" and Electricity, resemblance between, 235.
" by induction, 253.
" communicated by the electrical machine, or by a voltaic battery, 243.
" communicated by the Electro-Magnet, 250.
" developed in steel, 240.
" how induced by the voltaic battery, 244.
" how removed, 250.
" induced by electricity, 241.
" its importance to commerce and navigation, 237.
" produced by concentrated electricity, 242.
Magnetizing power of the conducting

Motion, impelled by a single force. 38.
" impelled by two or more forces. 39.
" incident and reflected. [illegible]
" laws of. 30.
" of animal or mechanical power, how impeded. [illegible]
" of the heavenly bodies not uniform. 266.
" of the heavenly bodies, why invisible. 161.
" of the heavenly bodies, why so regular. 27.
" perpetual. 33.
" produced by wheels, different directions given to the. 98.
" rapid or slow, how produced by the same mechanical power. 63.
" rectilinear changed to circular, and circular to rectilinear. 64.
" resultant. 30.
" terms applied to. 32.
" uniform, retarded, and accelerated. 32.
" when imperceptible. 161.
Mountains, height of, ascertained by the barometer. 102.
Mover of heat. 231.
Multiplying-glass. 181.
Music, why it sounds better in bare rooms. 131.
" difference between theory and practice of. 14.
" its theory a science, its practice an art. 14.
Musical chord, how obtained. 126.
" instruments, different tones of, how produced. 128.
" " tone of, why affected by the weather. 127.
" " wind and stringed, difference between. 126.
" strings, to what they owe their sonorous properties. 125.
Mutual attractions. 26.

Native Magnet or Loadstone, 222.
Natural History. 14.
" Philosophy. 14, 15, 17.
" " and Chemistry, difference between 15.
Natural Philosophy, principal branches of. 17.
" springs, how formed. 94.
Nautilus. 123.
Naval engagements, distance at which heard. 130.
Neap Tides. 294.
Near-sighted (or short-sighted) person, glasses suitable for. 173.
Needle of the Mariner's Compass, where placed. 226.
Negative electricity. 195.
" " how obtained from the electrical machine, 203.
Negatively electrified. 195.
Nesen. 257.
Neptune. 247, 253.
" (the planet,) by whom discovered. 257.
" distance from the sun unknown. 260.
" length of day unknown. 260.
" length of its year unknown. 260.
" moons of. 258.
Nerve, the optic, 173.
Newburyport, whispering gallery in a church of. 129.
Newcomen. 145.
" and Savery's steam-engine, 142.
Newton, Sir Isaac's, opinion respecting the tails of comets, 284.
" Sir Isaac's, discovery of gravitation. 51.
" Sir Isaac's, discovery with regard to the heterogeneous quality of light. 156.
" Sir Isaac, his opinion of the porosity of the earth. 24.
Niagara, Falls of. 139.
Nickel, possessed of magnetic properties. 222.
Night and day, cause of. 273.
" cause of the length of, 273.
Night-glass. 184.
Nitrogen. 98.
Nodes of a planet. 265.
Non-condensing steam-engines, 145.
Non-conductors of electricity, 196.
" or electrics, list of, 196
Non-electrics, 194.
North pole, 271.
" " of a magnet most powerful in north latitudes, 238
" wind, how produced, 108.

Northern Lights, 212.
Nucleus, 283.
Nut of a screw, 68.

Oar, why it appears bent when partly in the water, 169.
Oars, 58.
Objects, how seen, 158.
  " further from a concave mirror than its focus, inverted, 163.
  " how seen by the eye, 178.
  " reflected from a concave mirror, 164.
  " seen only in the direction of reflected rays, 162.
  " when invisible, 160.
Obtuse angles, 38.
Occultation, perpetual circle of, 288.
Octave, chord of an, how obtained, 126.
Œrsted, Professor, his discovery of electro-magnetic power, 240, 241.
Oil, specific gravity of, 87.
  " used for smoothing the surface of water, 92.
  " used for smoothing waves, 92.
  " why it ascends in the wick of a lamp, 75.
  " why it cools more speedily than water, 141.
  " why used in machinery, 69.
Olbers, Dr., his discovery of the planets Vesta and Pallas, 279.
Opaque bodies absorb part of the rays of light thrown upon them, 156.
  " bodies, how seen, 157.
  " substances, 153.
Opposition, 265.
Optic Nerve, 175. 178.
Opticians, their mode of fitting glasses to the eye, 175.
Optics, 17, 18. 152.
Oracle of Delphi and at Ephesus, 132.
Orbits, 259.
  " of the planets elliptical, 260.
  " of the planets, inclination of, shown by a section of the plane of the ecliptic, 265.
  " of the planets inclined to that of the earth, 263.
  " of the planets, oblique view of the inclination of the, 263.
Organized matter, 14.
Otto Guericke, the inventor of the air-pump, 113.
Overshot water-wheel, 96
Oxygen, 98.
  " a constituent part of water, 19.

Pails of water, why two can be carried more easily than one, 49.
Pallas, 257. 279.
  " diameter of, 261.
  " distance from the sun, 260.
  " length of the year of, 260
  " length of day in, 260.
  " perihelion of, 266.
Parabola, 45.
Paradox, Mechanical, 48.
  " the Hydrostatic, 81.
  " the Pneumatic, 123.
Parallax, 288.
Parallelogram, 38.
Parallel motion, appendages for, in the steam-engine, by whom applied, 145.
  " rays, effect of concave surfaces on, 174.
  " rays reflected from a concave surface, 166.
  " rays reflected by convex mirrors, 165.
  " rays, when made to diverge, 173.
Parallels of latitude, 272.
Parker's Exercises in Rhetorical Reading, 131.
Parry, 237.
Particles, all matter composed of, 23.
  " of matter, 19.
  " of a fluid, small, smooth, and globular, 74.
Partridges, guns suitable for, 46.
Parts of a body which move with the greatest velocity, 42.
Paxton's Introduction to the Study of Anatomy, 178.
Peculiarities of this volume described, 5.
Pencil of rays, 154.
Pendulum, 51.
  " Ballistic, 45.
  " how and by whom invented, 51.
  " length of, to vibrate seconds in different latitudes, 52.
  " vibrations of, on what dependent, 52.
  " vibrations of, how caused, 51.
Penumbra, 296.
Perfect conductors of electricity, 219.
Perigee, 266.
Perihelia of the planets, 266.
Perihelion, 265.

[illegible]

Planets, [illegible]
— [illegible]
— [illegible] on the planet Jupiter, [illegible]

[illegible]

Positive electricity, [illegible]
Power, [illegible]
— [illegible] of steam-engine, how expressed, [illegible]
Precession of the equinoxes, [illegible]
Press, Bramah's Hydrostatic, [illegible]

Presses, bookbinders', 68.
" cider and wine, 68.
Pressure of fluids, proceeds solely from the height of the column above, 80.
" lateral of fluids, from what it proceeds, 80.
" of a liquid exerted in all directions, experiment illustrating, 117.
" of a fluid in proportion to the height, 82.
" of fluids dependent on the height of the column above, and independent of the length or breadth of the column, 81.
" of the air on the surface of liquids, instruments to show, 114.
Primary Planets, 257.
" Planets, table of the distance, bulk, density, &c., of the, 301.
Prime conductor, 203.
Printing-presses, 73.
Prism, 186.
Properties, essential of all matter, 19.
" " and accidental, 19.
Projectile, 44.
" random of a, 46.
Projectiles, descent of, 43, 44.
Projection, force of, 40.
Protected sulphate of copper battery, 227.
Pulleys, power gained by use of, 60.
" practical use of, 61.
Pulley, 34. 59.
" the fixed, 59.
" the fixed, on what principle it operates, 59.
" the moveable, 59.
" the principle of the, 61.
Pump, the air, 109.
" height to which water can be raised by the, 106.
" the chain, 92.
" the common, 92. 106.
" the forcing, 92.
" the lifting, 107.
" the sucking, 106.
" boxes, 106.
Pumps, how water is raised to the boxes of, 114.
Pupil, 176.
" of the eye, 175.
" of the eye, dilatation and contraction of the, in some animals, 176.
Pyramid, why a firm structure, 49.
Pyrometer, 138.
Pyronomics, 17, 18. 132.

Quality of sound, of all musical instruments, by what affected, 126.
Questions to this volume, 6.
Quimby's Electrical Sawmill, 213.

Radii of a circle, 37.
Radius, 37.
" vector, 267.
Railroads, Steam-engine used on, 145.
Rain, 22.
" how produced, 86. 104. 133.
" how it differs from snow and hail, 86.
" water, a standard for computing specific gravity, 86.
" water, specific gravity of, 87.
Rainbow, 189.
Ram, the, 263.
Random of a projectile, 46.
Rare bodies, 23.
Rarefaction, 97.
" effect of, on the air, 108
Rarefied, meaning of the term, 97.
Rarity, 19. 23, 24.
Ray of light, 153.
Rays, incident and reflected, 157.
" of light entering a small aperture, 158.
" " " from different bodies, 154.
" " " from terrestrial bodies, diverging of, 154.
" " " passing obliquely from one medium to another, 167.
" " " when perpendicular to convex or concave mirrors, 162.
" " " when said to diverge, or to converge, 153.
" of the sun parallel at the earth, 172.
" parallel, converging and diverging, reflected from concave or convex surfaces, 165, 166.
" proceeding from one medium to another, 168.
Reaction, 35.
" caused by elasticity, 37.
Reaumur's scale for the thermometer 103.
Receiver, 109.
Rectangle, 38.

Sound of wind and stringed instruments. how respectively produced, 126.
  " produced by strings, quality of, how affected, 126.
  " quality of, affected by the furniture in a room, 130.
  " science of, the nature and laws of, 124.
  " uniform velocity of, available in measuring distances, 128.
  " velocity of, 127.
Sounds, how conveyed to great distances, 130.
  " when loudest, 124.
South Pole, 271.
  " " of a magnet most powerful in south latitude, 238.
  " wind, how produced, 108.
Southern Cross, 288.
Southwark bridge, arches of, raised by temperature of the air, 139.
Space passed over by a moving body, how estimated, 32.
Spaces through which falling bodies move, how they increase, 34.
Spark from a galvanic battery, action of a, 229.
Speaking, why difficult in a crowded house, 130.
Speaking-trumpets, 128.
Specific gravity, 29.
  " " of bodies heavier than water, how ascertained, 87.
  " " of bodies, instrument for ascertaining, 89.
  " " of bodies lighter than water, mode of computing, 88.
  " " of bodies, mode of computing, by whom discovered, 88.
  " " of the atmosphere, by what affected, 101.
  " " scales for ascertaining, 87.
  " " standard for estimating, 86.
  " " table of, 87.
Spectacles, the principles of, explained, 174.
Spectrum formed by a prism, how divided, 188.
Speed, in machinery, how increased or diminished, 64.
Spheres, proportion of to each other, 275.
Spherical bodies, why they roll down a slope. 48.
Spiral Tube, 208.
  " (electrical) tube, 215.
Spirit-level, or water-level, 76.
Sponge, 75.
Spots on the Sun, Dr. Herschel's opinion of the, 276.
Spring, hair and main of a watch, 53.
  " height of its rise, 94.
  " Tides, 293.
Springs, 22.
  " (natural) how formed. 94.
  " and rivulets, how formed, 93.
Square, 38.
Standard for computing the specific gravity of bodies, 86.
Stars, 257.
  " apparent motion of around the earth. 287.
  " distance of the, 286
  " double. treble, and quadruple. 286.
  " formed into clusters or constellations, 287.
  " how classed, 286.
  " how designated on a globe, 287.
  " how distinguished from planets, 258.
  " motion of the, 286.
  " never seen in their true position, 287.
  " number of, seen by Dr. Herschel in a quarter of an hour, 286.
  " Sir J. Herschel's calculation of the distance of, 286.
  " Telescopic, 286.
  " variation of their apparent magnitude, 286.
  " what supposed to be, 258.
  " why not seen in the daytime, 278.
Stationary Steam-engine, 150.
Steam, 74. 98. 133.
  " and vapor form clouds, 22.
  " condensation of, 133.
  " effect of, when confined, 141.
  " elastic force of, how increased or diminished, 141.
  " expansive power of, substituted for atmospheric pressure in the steam-engine, 143.
  " how made to act, 142.
  " or vapor, how produced, 141.
  " peculiar property of, 141.
  " pressure of, on what it depends, 141.
  " space occupied by before and after its conversion to water, 142.

Steam, supply of to machines, how regulated, 72.
  " temperature of, 141.
  " when visible, and when invisible, 142.
  " withdrawn from the principal cylinder of the steam-engine, 142.
Steam-engine, 142.
  " acting parts of described, 143.
  " double action of the, 143.
  " how constructed, 145.
  " inventors of the, 145.
  " locomotive, Hinkley and Drury's, 149.
  " Newcomen and Savery's, 142.
  " power of, how expressed, 145.
  " power of the, as described by Mr. Jeffrey, 145.
  " the atmospheric, 142.
  " the condensing and non-condensing, or the high and the low pressure, 145.
  " Watts' double-acting, condensing, 143.
  " Watts' improvements in the, 142.
Steam-engines, how regulated in the supply of steam, 72.
Steam-pipe, 143.
Steel, rendered magnetic, 240.
Steelyard, 55.
  " how managed, 56.
Stereo-electric current, 255.
Stethescope, 127.
Stilts, how used by shepherds in France, 48.
Straight Jet, 118.
Streams, velocity of, how ascertained, 91.
Strings of musical instruments, height and depth of tone of, on what dependent, 125.
Strings of musical instruments, to what they owe their sonorous properties, 125.
Sucker, 114.
Sucking-pump, 106.
Sugar and salt, particles of, smaller than those of water, 20.
  " why it readily absorbs moisture, 75.
Sulphate of Copper Battery, 226.
Summer rays, 270.
Summer solstice, 275.
Sun, 257. 275.
  " an entire image of, reflected from every portion of the surface of a sheet of water on which it shines, 158.
  " cause of the red appearance of, 187
  " cubic magnitude of the, 275.
  " diameter of the, 261. 275.
  " light of the, time employed in coming to the earth, 169.
  " heat of the, 276.
  " its effect on the tides, 293.
  " length of day in the, 260.
  " probably inhabited. 276.
  " rays of the, parallel at the earth 172.
  " revolution of around its axis, 276.
  " spots on the, 276.
  " table of the bulk, density, diameter, &c., of the, 301.
  " the centre of the solar system, 259.
  " time occupied by his light in reaching the earth, 280.
  " total eclipse of in 1806, 298.
  " what supposed to be, 258.
  " when nearest to the earth, 265.
Sun's heat on the surface of the earth, effect of the, 103.
  " light, why white, 188.
  " rays, how we are shielded from the intensity of the, 102.
Superior conjunction, 265.
  " planets, 260.
Surinam Eel, 216.
Swimming, the effect of action and reaction, 36.
  " how a person ignorant of may float, 87.
  " why more difficult in fresh than in salt water, 87.
Synthesis, or combination, 15.
Syringe, the condensing and exhausting, 117.
Syringes, for procuring fire, 138.
System, the Solar, 257.

Table of Diameters, Distances, daily and annual revolutions, bulk, density, &c., of the Sun and Primary planets, 301.
Tables of equation of time, 300.
Tackle and Fall, 61.
Tail of a comet, 283.
Tangent, 42.
  " of a circle, 38

Tantalus' Cup, 95.
Taurus, 263.
Telegraph, Electro-Magnetic, 251.
Telescope, 183.
  " Astronomical, 184.
  " Terrestrial, 184.
Telescopes, kinds of, 183.
  " refracting, two kinds of, 184.
Telescopic stars, 286.
Tellurium, Electrical, 206.
Temperature of steam, 141.
Tenacity, 19. 25.
Tender of a Locomotive Steam-engine, 148.
Ten Eyck and Henry, powerful electro magnet formed by, 249.
Tension of a musical string, how it affects its tone, 126.
Terrestrial Telescope, 184.
Thales, of Miletus, his discovery in electricity, 194.
Theology, meaning of, 13.
Theory of Music, 16.
Thermal effects of light, 191.
Thermo-electric batteries, 256.
Thermo-electricity, 196. 255, 256.
  " " Prof. Seebeck's discovery in, 255.
Thermometer, 101. 103.
  " how it differs from a barometer, 103.
  " scales of the, 103.
Thickness, 21.
Threads of a screw, 68.
Thunder-cloud, distance of a, how ascertained, 128.
Thunder-house, 211.
Thunder-storms, 215.
  " " dangers in, 216.
  " " safest position in, 216.
Tides, how caused, 292.
  " irregularities of the, 294.
  " Neap, 294.
  " Spring, 293.
  " theory of the, the most imperfect of astronomical hypotheses, 294.
Time, 298.
  " difference between true and apparent, 300.
  " employed in the use of machinery, 170.
  " kept by clocks, when same as that of the sun, 300.
  " of moving body, how estimated, 32.
  " solar and sidereal, difference between, 298.
Time, (true) cannot be measured by the sun, 300.
Tin-foil, use of in the Leyden Jar, 199.
Tissue figure, 205.
Toggle-joint, 73.
Tone, height and depth of, on what dependent, 125.
  " of a musical string, how affected by tension, 126.
Tones of the human voice, how varied, 131.
Tonnage of a vessel, mode of computing, 85.
Torpedo, 216.
Torricelli, 110.
Torricellian Vacuum, 100. 110.
Torrid zone, weather prevalent in the, 108.
Total eclipse of the sun, darkness produced by, 155.
  " eclipse of the sun, duration of a, 298.
  " eclipse of the sun in 1806, 298.
Towel, the end of a, left in a vessel of water, will empty it, and why, 75.
Trade-winds, 108.
Transfer of fluids from one vessel to another, 121.
Transit of a planet, 277.
  " of Venus and of Mercury, 278
Translucent substances, 153.
Transparent bodies, 152.
Trees uprooted by means of the hydrostatic press, 85.
Tropic, meaning of the term, 272.
  " of Cancer, 272.
  " of Capricorn, 272.
True focus of a concave mirror, 163.
Trumpets, (hearing,) used by the deaf, 129.
  " principle on which they are constructed, 129.
Tube, the mercurial or water, 114.
Tubes, Acoustic, 130.
Tufts', Otis, stationary steam-engine 150.
Tumbler of water, cause of moisture on, in warm weather, 133.
Twins, The, 263.

Undershot water-wheel, 96.
Undulations of an elastic medium, the supposed cause of light, 153
Undulatory Theory, 153.
U magnet, 235.

Uniform motion, 32.
" " how produced, 32.
Universal Discharger, 206.
Unmagnetized steel, how endued with polarity, 243.
Unorganized matter, 14.
Upward pressure of fluids, by what caused, 81.
Uranus. *See "Herschel," or the "Georgium Sidus,"* 257, 266, 282.
" light and heat of, 282.
" moons or satellites of, 256, 282, 302.
Ursa Major, 299.

Vacuo, in, 71.
Vacuum, 100.
" a perfect, never produced by the air-pump, 109.
" a perfect, pressure of the air against, 112.
" how produced in the common pump, 105.
" in the cylinder of a steam-engine, 42.
" the Torricellian, 100, 110.
Valve, 106.
" the sliding, of a steam-engine, 148.
" the condensing, of an air-pump, 110.
" the exhausting, of an air-pump, 110.
Valves in air pumps, how they open, 111.
" how made, 106.
" of a common pump, 106.
" of the air-pump, 106.
Vancouver, 237.
Vapor, 98.
Variation of the magnet, 236.
" of the magnetic needle, by what caused, 241.
" of the magnetic needle subject to changes, 237.
Velocity, 30.
" absolute and relative, 31.
" how measured, 31.
" of a body in motion around a point, on what dependent, 161.
" of a heavenly body, increase of explained, 267.
" of falling bodies, 27.
" of machinery in manufactures, how regulated, 72.
" of rivers, wind, &c., &c., &c., of a musket ball, of a cannon ball, of the equatorial regions, of the earth's centre, 31.
Velocity of running water at its surface, 91.
" of running water, how ascertained, 91.
" of steam-carriages, of sailing-vessels, of race-horses, &c., 31.
" of water in running streams, 91.
" to what proportioned, 31.
Ventriloquism, 131.
" art of, not unknown to the ancients, 132.
Ventriloquist, peculiar power of the, 131.
Venus, 257, 277.
" diameter of, 261.
" distance from the sun, 260.
" heat and light on, 277.
" length of day in, 260.
" length of the year of, 260.
" perihelion of, 266.
" phases of, 275.
" revolution of, 259.
" sometimes seen in the daytime, 276.
" when called morning, and when evening star, 277.
Vernal equinox, 275.
Verrier, 263.
Verrier's discovery of the planet Neptune, 257.
Vertical line, 27.
" lines always perpendicular to the surface of the earth, 27.
Vesper, 277.
Vessels, tonnage of, method of computing, 85.
Vesta, 257, 279.
" diameter of, 261.
" distance from the sun, 260.
" length of day unknown 260.
" length of the year of, 260.
" perihelion of, 266.
Vibrations of a pendulum, how caused, 51.
" of a sonorous body, their effect on the air, 125.
" of sonorous bodies, the foundation of the Science of Harmony, 126.
" of strings of musical instruments, 125.
Virgin, 263.
Virgo, 263.

Fig. 41. What does Fig. 41 represent? Explain it.

Fig. 42. What does Fig. 42 represent? Explain it.

Art. 90.—What is an inclined plane? What figure represents an inclined plane?

Fig. 43. Explain Fig. 43. To what is the advantage gained by the use of the inclined plane in proportion? What follows from the greater or less inclination of the plane? Give some instances of the application of the inclined plane. Is any time gained by the use of the inclined plane? Upon what principle are chisels and other cutting instruments, which are sloped only on one side, constructed?

Art. 91.—Of what does the wedge consist?

Fig. 44. What does Fig. 44 represent? Explain it. To what is the advantage gained by the wedge in proportion? Of what use is the wedge? Give some examples of the wedge.

Art. 92.—Of what does the screw consist? Of how many parts is it generally composed? What are they?

Fig. 45. What figure represents the screw and the nut? Explain the figure.

Fig. 46. How does Fig. 45 differ from Fig. 46? Is the screw a simple or compound power? How is the power of the screw estimated? How does the closeness of the thread affect the power? What is the use of the screw? How can its power be increased? To what is the screw applied? What is meant by friction in machinery? How many kinds of friction are there? What are they? How is the rolling friction produced? The sliding? Which is overcome with the less difficulty, the rolling or sliding? What allowance must always be made, in calculating the power of a machine? What proportion of the power is usually computed to be destroyed by friction? Between which is friction the less, rolling bodies or those that slide? What causes friction? In what proportion is it diminished? In what manner can it be lessened? What is the use of wheels? In what proportion do they overcome the obstacles, such as stones, &c., in the road? Why, in descending a steep hill, are the wheels of a carriage often locked? How do castors, which are put upon furniture, facilitate the moving of it? How is the motion of all bodies influenced?

Art. 93.—What is meant by a medium? Give examples.

Art. 94.—To what is the resistance of a medium in proportion? What illustration is given? When would a machine be perfect?

Art. 95.—Of what does the main-spring of a watch consist? What is its use? D -ring exert a stronger force when closely coiled, or when partly loosened? What is done in order to correct this inequality?

Fig. 47. What does Fig. 47 represent? Explain it.

Art. 96.—What is a governor?

Fig. 48. Explain Fig. 48. What is said of the use of the governor?

Art. 97.—Of what does the knee-joint, or toggle-joint, consist? In what proportion does it increase in power?

Fig. 41.

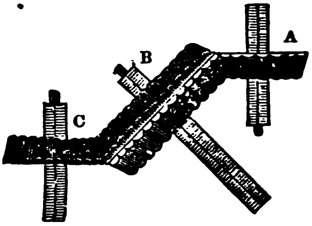


Fig. 42.

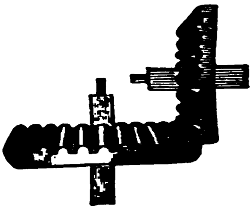


Fig. 43.

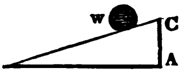


Fig. 44.

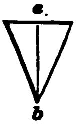


Fig. 45.

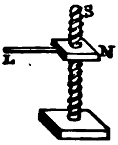


Fig. 46.

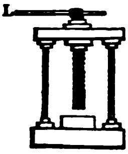


Fig. 47.

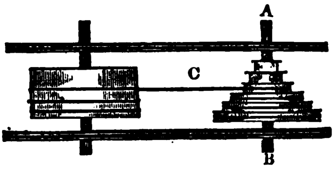


Fig. 48

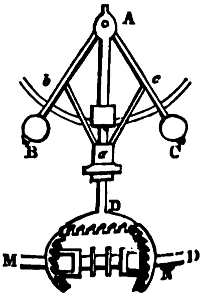


Fig 49 What does Fig. 49 represent? Explain the figure. Give an instance of the operation of the toggle-joint. What is its use in printing-presses?

HYDROSTATICS.

Art. 98.—Of what does Hydrostatics treat?

Art. 99.—What is a fluid? Does the attraction of cohesion have much influence on the particles of fluids? What follows from this?

Art. 100.—How do fluids differ from liquids? Can water be compressed? What is supposed to be the primary cause of the fluid form of bodies? What effect has heat upon bodies? What illustration is given? Why do fluids gravitate in a more perfect manner than solids? What is inferred from the slight degree of cohesion in the particles of fluids? Why smooth? Why globular? Why cannot fluids be formed into figures, or preserved in heaps? What do you understand by capillary attraction? Explain the reason of it. Explain why the same takes place in all porous substances. Explain all the circumstances attending the burning of a lamp. Explain the experiment with the glass plates.

Art. 101.—What is meant by the level or equilibrium of fluids? Have all fluids a tendency to preserve this equilibrium? What follows from this? Of what is this level or equilibrium of fluids the natural result? How does the gravitation of solid bodies differ from that of fluids?

Art. 102.—Do fluids of different densities all preserve their own equilibrium? What illustration is given to prove this?

Art. 103.—Upon what principle is a water-level constructed? Of what does it consist? For what is it used?

Fig. 50. What figure represents a water-level? Explain the figure.

Art. 104.—In what manner do solid bodies gravitate? What is the centre of gravity? What effect has gravity on the particles of fluids?

Art. 105.—How is the pressure of fluids exerted? How long will the particles of fluids remain at rest?

Fig. 51. Explain Fig. 51.

Fig. 52. What does Fig. 52 represent? Explain it. If the equality of the pressure be undisturbed, what will follow? If the fluid be agitated, when will it again come to a state of rest? How is the downward pressure of fluids shown? The lateral pressure? The upward pressure?

Art. 106.—To what is the pressure of a fluid in proportion? In what direction is this pressure exerted? What illustrations are given to prove this? Why can a bottle, filled with water or any other liquid, be let down to any depth without injury? What experiment is mentioned in the note? What opinion have some philosophers expressed?

Art. 107.—What causes the lateral pressure? What follows from this?
Fig 53. Explain Fig. 53.

Art. 108.—Does the length or the width of the vessel in which a fluid is contained have any effect upon the lateral pressure? By what is it affected?

Art. 109.—How does the lateral pressure on one side of a cubical vessel compare with the pressure downwards? How would you explain this?

Art. 110.—What causes the upward and downward pressure?
Fig. 54. Illustrate this by Fig. 54.

Art. 111.—Upon what does the force of pressure depend? What is meant by the hydrostatic paradox? What is the use of the hydrostatic bellows?
Fig. 55. What figure represents the hydrostatic bellows? Explain the figure. What is the fundamental principle of Mechanics? Is this the principle of the hydrostatic bellows?

Fig. 49.

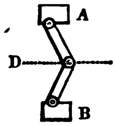


Fig. 50.

Fig. 51.

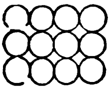
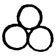


Fig. 49.



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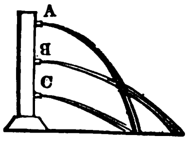


Fig. 55.

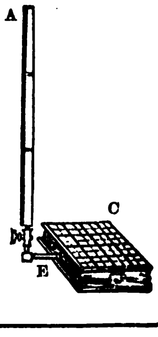


Fig. 54.

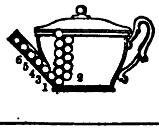


Fig. 56. What does Fig. 56 represent? Explain why fluids press according to the heights, and not according to the quantity.

Art. 112.—What fact is mentioned in this number in regard to the pressure of water? Upon what principle is Bramah's hydrostatic press constructed?

Fig. 57. What figure represents this? Explain the figure. To what uses is this press applied?

Art. 113.—When will one fluid float upon another?

Art. 114.—What is stated with regard to a body specifically lighter than a fluid? What illustration is given of this? How do the specific gravities of water and cork compare with each other? Upon what principle is it that boats, ships, &c., are made to float upon the water? What rules have been formed from the knowledge of the specific gravity of water and the materials of which vessels are composed?

Art. 115.—What standard has been adopted to estimate the specific gravity of substances in general? Why could not metals have been adopted? Why is distilled water used? What bodies will sink when immersed in water? What will float? What is the weight of a cubic foot of water? What is the use of the table? How does the specific gravity of living men compare with that of water? Which is the greater, the specific gravity of sea water, or of lakes and rivers? Why?

Art. 116.—How is the specific gravity of bodies that will sink in water ascertained? What illustration is given?

Fig. 58. Explain Fig. 58. Why will gold weigh less in the water than out of it? How does this upward pressure of the particles compare with the downward pressure of a quantity of water of the same dimensions? What follows from this? What rule is given with regard to all bodies heavier than water that are immersed in it? What is the specific gravity of a body? What is the reason that a bucket of water, drawn from a well, is heavier when it rises above the surface of the water, than while it is below it?

Art. 117.—How can the specific gravity of a body that will not sink in water be ascertained? What illustration is given? By whom was the method of ascertaining the specific gravities of bodies discovered? In what manner did he ascertain it?

Art. 118.—What is an hydrometer? Upon what principle is it constructed? Explain its construction. In what proportion does the scale sink?

HYDRAULICS.

x. 119.—Of what does Hydraulics treat? What retards the motion of water? Why does the surface of a canal or river have a greater velocity than any other part?

x. 120.—Does the fulness of a vessel, from the orifice of which a fluid is running, have any effect upon its velocity?

Fig. 56.

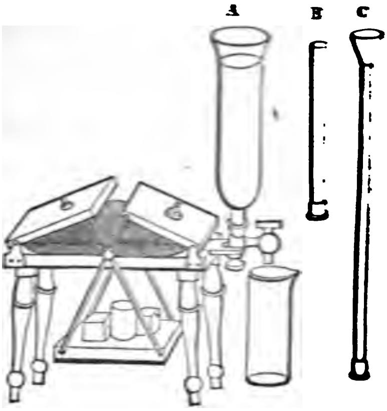
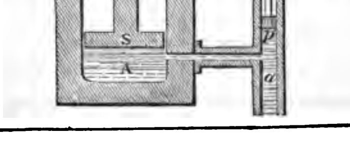


Fig. 58.

Fig. 57.



Art. 121.—When a fluid spouts from several orifices in the side of a vessel, from which is it thrown to the greatest distance?

Art. 122.—What effect will a pipe, fitted to an orifice, have with regard to the quantity discharged? What will be the effect if the pipe project into the vessel? How can the quantity discharged through a pipe or orifice, be increased? Why will heat increase it?

Art. 123.—How can the velocity of a current of water be ascertained?

Fig. 59. What does Fig. 59 represent? Explain it. How is the rapidity of the current estimated? What is the use of the instrument?

Art. 124.—What causes waves? What is sometimes done to remove this friction?

Art. 125.—What instruments are used for raising liquids?

Art. 126.—Where is the chain-pump used? What figure represents it?

Fig. 60. Explain the figure.

Art. 127.—What is said of the screw of Archimēdes?

Fig. 61. Explain the use of the screw by Fig. 61.

Art. 128.—How are springs and rivulets formed?

Fig. 62. Explain Fig. 62.

Art. 129.—How high will a spring rise?

Art. 130.—How are fountains formed? How high will the water spout through the ducts? What prevents the fluid from rising to the same height with the reservoir?

Fig. 63. Explain the method of making artificial reservoirs by Fig. 63.

Art. 131.—What is the siphon?

Fig. 64. What figure represents a siphon? Explain it. In what manner is the siphon used? How can the siphon be used to show the equilibrium of fluids? How high will the liquid rise in each side of the siphon? What is Tantalus' cup?

Fig. 65. What does Fig. 65 represent? Explain it.

Art. 132.—How, and for what purposes is water used as a mechanical agent? How many kinds of water-wheels are there? What are they?

Art. 133.—What is the overshot wheel? Where does it receive its motion?

Fig. 66. Explain Fig. 66. What causes the wheel to turn? How does this wheel compare in power with the other water-wheels?

Art. 134.—What is the undershot wheel? Where does it receive its motion?

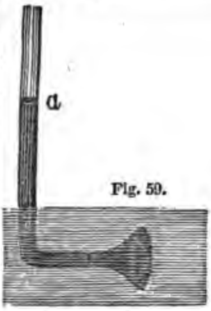
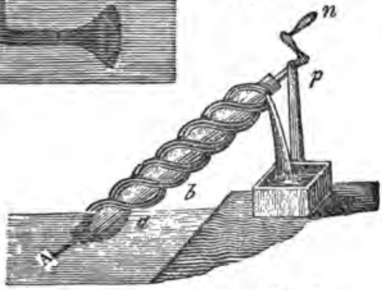


Fig. 59.



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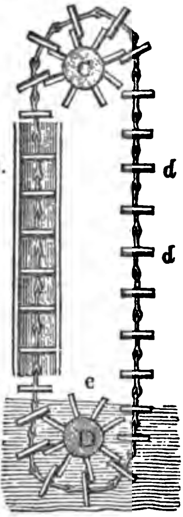
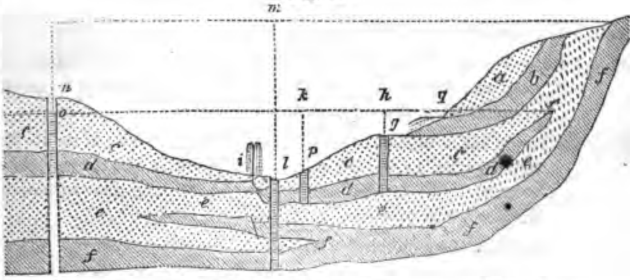


Fig. 61.

Fig. 62



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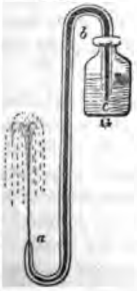


Fig. 64.

Fig. 65.

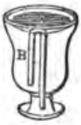


Fig. 66

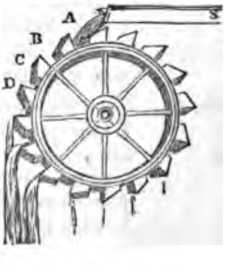


Fig. 67. What does Fig. 67 represent? How does this wheel differ from the overshot?

Art. 135.—What is the breast-wheel? How is it set in motion?

Fig. 68. What figure represents the breast-wheel? Explain it. To what is the motion given to the wheels which have been described, communicated?

PNEUMATICS.

Art. 136.—Of what does Pneumatics treat?

Art. 137.—What is the air which we breathe? How far does it extend above the surface of the earth? Does it possess properties common to fluids in general? How does its specific gravity compare with that of water? Of what two principal ingredients does the air consist? What is the proportion of these parts to each other?

Art. 138.—What other fluids are named belonging to the class of elastic fluids?

Art. 139.—Have the air and other similar fluids weight? With what power does the heat [illegible] in aeriform fluids?

Art. 140.—What two principal properties has the air?

Art. 141.—What is the weight of a column of air one inch square at the base, and reaching to the top of the atmosphere? Is the pressure exerted equally in all directions?

Art. 142.—What is meant by the elasticity of the air? How do the aeriform fluids differ from liquids? When is the air said to be rarefied? When condensed? Is the air near the surface of the earth rare or dense?

Art. 143.—How does the air become a mechanical agent?

Art. 144.—What is a vacuum?

Art. 145.—What is a barometer? What does the word barometer mean? What is a thermometer? What does the word thermometer mean? What is a hygrometer? What does the word hygrometer mean?

Fig. 69. What figure represents a barometer? Explain its construction. What height of mercury is the pressure of the atmosphere capable of sustaining? What effect has the pressure of the atmosphere on the mercury in the tube? In what proportion does the mercury rise and fall? In what way can barometers be made of other fluids? Why is mercury used in preference to any other fluid? Is the air heaviest in wet or dry weather? On what principle is the pressure of the atmosphere on the mercury, in the cup of a barometer, exerted? What follows from this? For what other purpose, besides measuring the pressure of the atmosphere, and foretelling the variations of the weather, is the barometer used? Is the air the more dense at the surface of the earth or upon a hill? What is a thermometer? Fig. 70 What figure represents a thermometer? Explain its construction. What effect have heat and cold on most substances? What follows from this? Whose scale is generally used in this country? For what is the hygrometer used? Of what kind of substances may it be constructed? What experiment is given in the note to show the quantity of moisture raised from the ground by the heat of the sun?

Fig. 67.

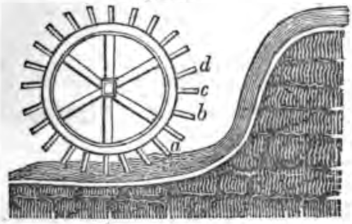
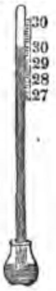


Fig. 69.



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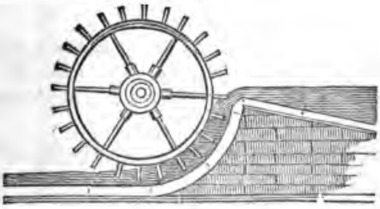
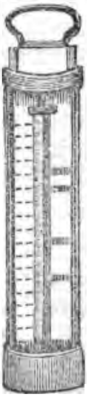


Fig. 70



Art. 146.—Is air impenetrable, like other substances? How is this shown? Upon what principle is the diving-bell constructed?

Fig. 71. What figure represents the diving-bell? Why does not the water rise in the bell? Explain the figure.

Art. 147.—By what means is water raised in the common pump? How is the pressure removed?

Fig. 72. What figure represents the common pump? Explain it. Which of the mechanical powers is the handle of the pump? How high can water be raised by the common pump? Why? Why is the common pump sometimes called the lifting-pump?

Art. 148.—How does the forcing-pump differ from the common pump?

Fig. 73. What figure represents the forcing-pump? Explain it.

Art. 149.—What is wind? In what two ways may the motion of the air be explained? Explain the manner in which the air is put in motion. How are the north, south, east, and west winds produced

Art. 150.—What is an air-pump? What is the vessel called from which the air is exhausted? On what principle are all air-pumps constructed? Can a perfect vacuum ever be obtained?

Fig. 74. Describe the air-pump represented by Fig. 74.

Fig. 75. Describe Wightman's patent lever air-pump, represented by Fig. 75.

Art. 151.—Experiments with the air-pump.

Fig. 76. What does Fig. 76 represent? Explain the experiments that are made with them.

Fig. 77. What does Fig. 77 represent? Explain the experiments made with it.

Fig. 71.

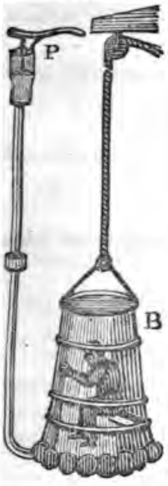
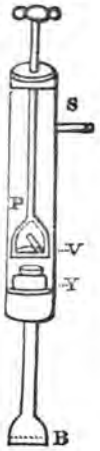


Fig 72.



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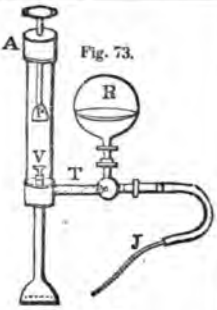

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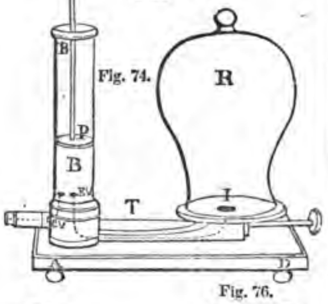


Fig. 75.

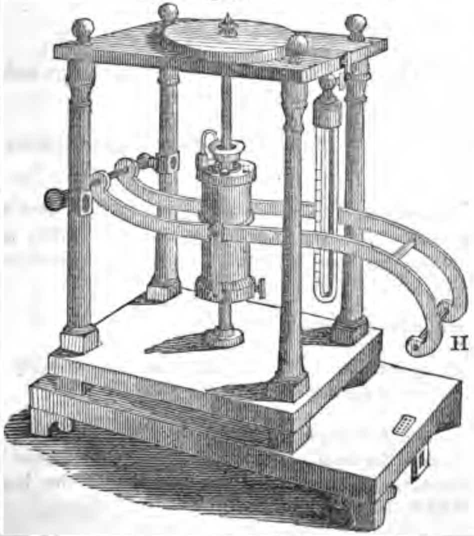


Fig. 76.

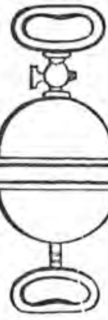


Fig. 77.

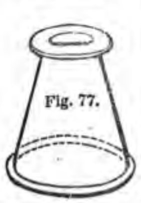


Fig. 92. Explain Fig. 92.

Art. 158.—Upon what is the science of harmony founded? How is the chord of an octave produced? How is the chord of a fifth produced? How is a musical chord produced? A discord?

Art. 159.—Upon what does the quality of the sound produced by strings depend? Upon what does that produced by wind instruments depend? What strings produce the lowest tones? How may different tones be produced from the same string? How may different tones be produced from the same wind instrument?

Art. 160.—What, in some degree, affects the quality of the sound of all musical instruments? What effect have heat and cold on the materials of which the instrument is made? What follows from this? Why are most musical instruments higher in tone, or sharper, in cold weather?

Art. 161.—Through which is sound communicated more rapidly, and with greater power, through solid bodies, or the air? How fast is it conducted by water? How fast by solids? What examples are given to show that sound is communicated more rapidly through solid bodies than the air or fluids?

Art. 162.—What is a stethescope? Of what does it consist? For what is it used?

Art. 163.—How fast does sound move? Does the force or direction of the wind make any difference in its velocity? What advantage results from this uniform velocity of sound? How can the distance of a thunder-cloud be ascertained?

Art 164.—How is an echo produced? Why cannot an echo be heard at sea, or on an extensive plain? How must a person stand in order to hear an echo? By what law is sound communicated and reflected? What anecdote is related of Dionysius? Upon what principle are speaking-trumpets constructed? Explain the manner in which the vibrations of the air are reflected. Upon what principle are hearing-trumpets constructed? How far does the musical instrument, called the trumpet, act upon the principle of the speaking-trumpet? How can the continued sound, given by some shells, when held near the ear, be explained?

Art 165.—Upon what principle may whispering-galleries be constructed?

Art 166.—In what way can sounds be conveyed to a much greater distance than through the air? What are the tubes, used to convey sounds, called? Why do the softer kinds of furniture in a room affect the quality of the sound? What general rule is given with regard to the reflection of sound? Is the air a better conductor when it is humid, or when it is dry? Why can a sound be heard better in the night than in the day?

Art. 167.—How is the sound of the human voice produced? How are the tones varied and regulated? Upon what does the management of the voice depend? What is ventriloquism? Was this art known to the ancients? What is supposed, by some authors, concerning the responses at Delphi, Ephesus, &c.? Is ventriloquism a natural gift, or an acquired one?

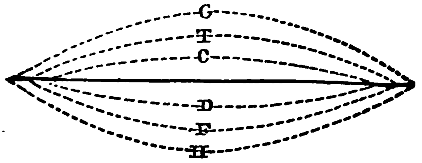
PYRONOMICS.

Art. 168.—What is Pyronomics? What is said in regard to the nature of heat? Is it ponderable or imponderable? What effect has heat upon bodies? What two forces continually act in opposition to each other? In what can the effect of heat be seen? How does it separate the particles? What would be the effect were the heat removed? Upon what has heat the most remarkable effect? How does it affect it? What effect has heat upon air? How is rain produced? What is stated with regard to heat? Can the progress of heat be arrested? What is caloric? In what two states does heat exist? What is free heat? Give some examples of free heat. What is latent heat? Give some examples of latent heat. How are the terms heat and cold generally used? What illustration of this is given?

Art. 169.—What are the three principal effects of heat on bodies to which it is applied? Give an example of each. What are the sources of heat?

Art. 170.—In what way does heat tend to diffuse itself? Why do bodies of the same absolute temperature appear to possess different degrees of heat? What illustration of this is given? What appears from this?

Fig 92.



Art. 171.—What causes the difference in the warmth of substances used for clothing?

Art. 172.—In what two ways is heat propagated? When is it propagated by conduction? When is it propagated by radiation?

Art. 173.—Do all bodies conduct heat with the same degree of facility? What bodies are the best conductors? In what order do the metals stand with respect to their conducting power? Is wood a good conductor of heat? Why are wool, fur, &c., so efficacious in preserving the warmth of the body? What is related in the note with regard to the conducting power of heat?

Art. 174.—What bodies reflect the heat? What bodies absorb the heat? Why do bright bodies, when placed near the fire, seldom become heated? Will snow melt most readily under white or black cloth?

Art. 175.—What effect is produced on all bodies when violently compressed or extended? What experiments are here related to illustrate this? What is said of the air when strongly compressed?

Art. 176.—Into what classes are all substances, as affected by heat, divided? What substances are combustible? What substances are incombustible?

Art. 177.—What is a pyrometer? Of what does it consist? How does Wedgewood's pyrometer measure high temperatures?

Art. 178.—What is the most obvious and direct effect of heat on a body? What application of this principle is related in the note? What is said of the effect of heat and cold on glass? When hot water is suddenly poured into a cold glass, why will the glass crack? When cold water is applied to a heated glass, why will the glass crack?

Art. 179.—Is the expansion caused by heat in solid and liquid bodies the same in all substances? How do aëriform fluids differ, in this respect, from solid and liquid bodies? Upon what does the expansion of solid bodies in some degree depend? Why has heat more power over gases and vapors?

Art. 180.—What effect has heat and cold upon the density of all substances? What exception is there to this remark? Why are the vessels, containing water and other similar fluids, so often broken when the liquid freezes in them? Why does ice float upon the water, instead of sinking in it? What is stated in the note with regard to this property of water?

Art. 181.—Can all bodies be raised to the same temperature by the same quantities of heat? What bodies retain their heat the longest?

Art. 182.—What becomes of the heat which is thrown upon a bright or polished surface? How do the angles of incidence and reflection compare with each other?

Art. 183.—When is water converted into steam or vapor?

Art. 184.—How does the temperature of the steam compare with that of the liquid from which it is formed while it remains in contact with that liquid?

Art. 185.—By what is the elasticity of steam increased and diminished? Upon what does the amount of pressure, which steam exerts, depend?

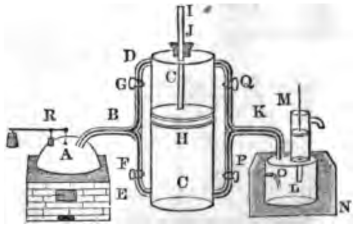
Art. 186.—What is the great and peculiar property of steam, on which its mechanical agencies depend?

Art. 187.—What is the steam-engine?

Art. 188.—How much larger space does steam occupy than water? By what mode is steam made to act? By what impulse does the piston rise? What causes the piston to descend? What improvement did Mr. Watt introduce into the steam-engine?

Fig. 93. What does Fig. 93 represent? What are the principal parts? What does A represent? What does C represent? What does B represent? What does K represent? By what is the steam led off from the cylinder? What does L represent? What does O represent? What does M represent? What does N represent? What does R represent? When the valves are all open, what becomes of the steam? When the valves F and Q are closed, and G and P open, upon what does the steam press? What does the cylinder draw with it in its descent? Which of the mechanical powers is this working-beam? What are attached to this working-beam? What is their use? What becomes of the steam when the stop-cocks G and P are closed, and

Fig. 93.



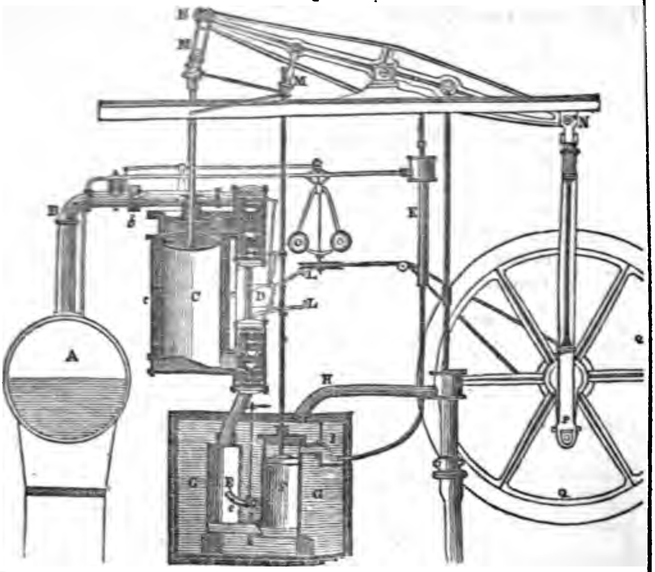
F and Q are open? How is the regular and continued motion produced? To what is this motion of the piston communicated? What is the use of the air-pump M? For what is the safety-valve R used?

Art. 189.—How is the power of a steam-engine expressed? What is an engine of 100 horse power?

Art 190.—What are the principal forms in which the steam-engine is constructed? How do they differ from each other? What becomes of the steam after having moved the piston in the non-condensing engines? What kind of engines is generally used on railroads? What becomes of the steam after having moved the piston in the condensing engines?

Fig. 94. What does Fig. 94 represent? What does A represent? What does B represent? What does C represent? What does D represent? What does E represent? What does F represent? What does G G represent? What does I represent? What does K represent? What does L L represent? What does M M represent? What does N N represent? What does O O represent? What is said of the governor?

Fig. 94.



Art. 191.—Describe the *locomotive* steam-engine.

Fig. 95. In Fig. 95, what do F and D represent? What do the following references respectively represent, namely, S S S? B B B? *p p p p?* C C? X? L? P? N N? R G K K?

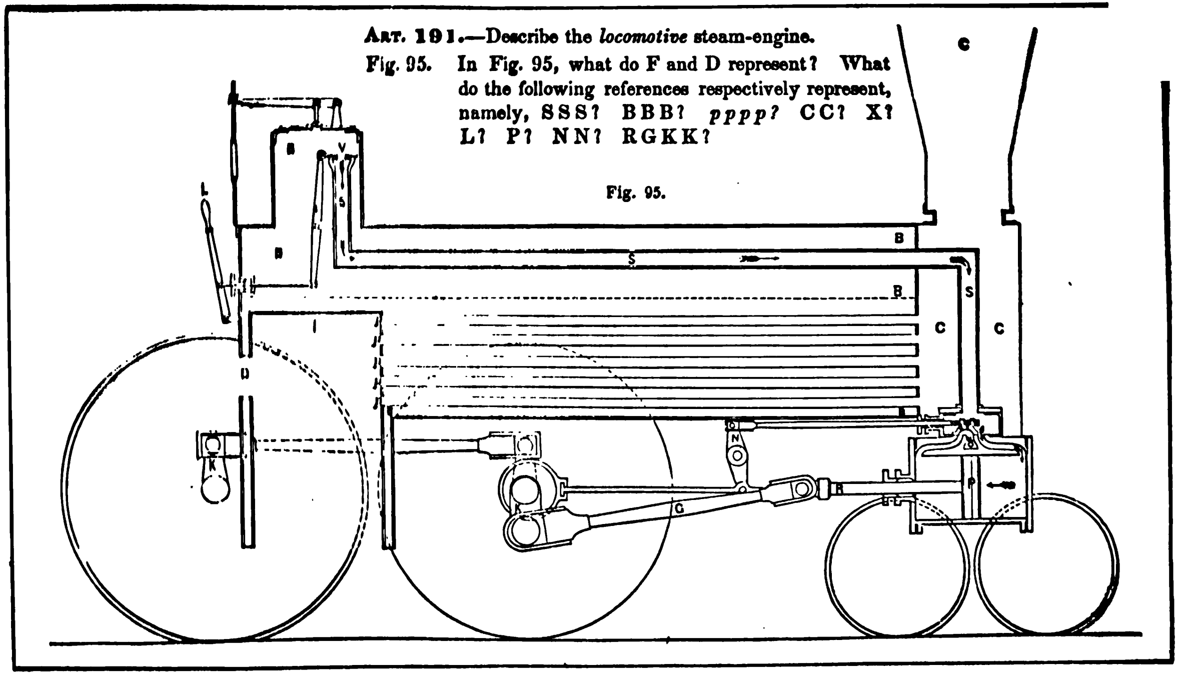


Fig. 95.

Art. 225.—What is a single microscope? What is the use of the microscope? What figure represents a microscope?

Fig. 116. Explain Fig. 116. What lenses have the greatest magnifying power? What lenses have the shortest focus?

Art. 226.—Of what does a double microscope consist? What is the use of these two lenses?

Fig. 117. What does Fig. 117 represent? Explain the figure.

Art. 227.—What is the solar microscope? Of what does it consist? By what, in this microscope, are the sun's rays reflected and [illegible]? For viewing what objects only is the microscope [illegible]? How do these microscopes, used in viewing opaque objects, differ from these? How is the magnifying [illegible]? How is the magnifying power of a single microscope ascertained? Illustrate this. How is the magnifying power of the compound microscope ascertained? In what proportion is the magnifying power of the solar microscope? Illustrate this. How may a lens be made to magnify or diminish an object?

Art. 228.—What is the magic lantern? How are objects viewed by the magic lantern generally represented? What figure represents a magic lantern?

Fig. 118. Explain Fig. 118. In what proportion will the size of the image increase or diminish?

Art. 229.—What is a telescope? How many kinds of telescopes are there? What are they? What is a refracting telescope? What is a reflecting telescope? Why is the image of an object seen through a refracting telescope, less clear and perfect than when seen through a reflecting telescope? How many kinds of refracting telescopes are there? What are they? How do they differ the one from the other?

Fig. 119. What does Fig. 119 represent? Explain the figure.

Fig. 116.

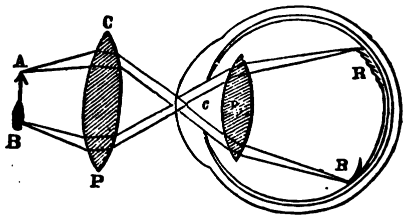


Fig. 117.

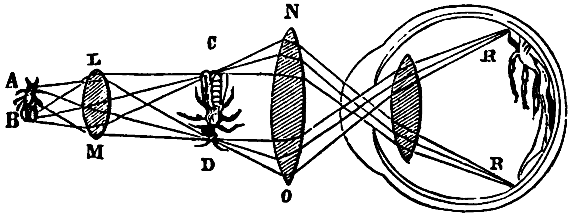


Fig. 118.

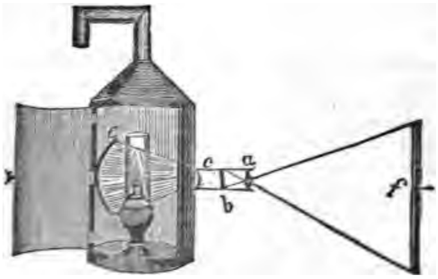
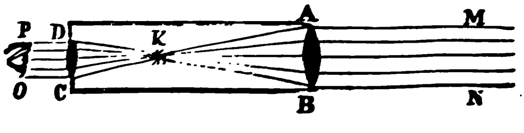


Fig. 119.



ART. 248.—Of what does the kaleidescope consist? From what is the word kaleidescope derived, and what does it mean? By whom was the instrument invented? What is here said with regard to the kaleidescope? In what way does Optics treat of light? What is the thermal property of light? Are the thermal properties of the rays the same, or different in each color of the prism? How do they differ? How do the chemical agencies differ? Do these powers exist in all light, or in solar light only? Where is the greatest heating power found? Where the greatest chemical power? Where the greatest optical power? In what are the chemical powers of light shown? Name the experiments and explain them. Explain the art of Photography, or Heliography. By what name is it now known? How else are the chemical effects of light seen?

Fig. 120.

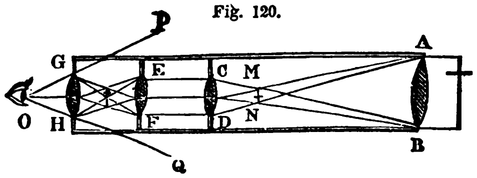
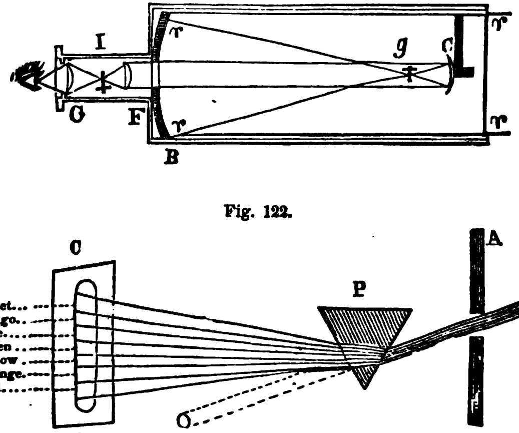


Fig. 121.



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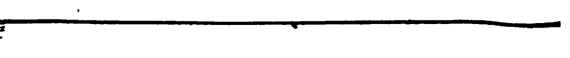


[illegible]

Art. [illegible].—[illegible] How can electricity be seen? How [illegible] What illustration of this is given? [illegible] the power of [illegible] What are electrics? What are non-electrics? [illegible] with regard [illegible] By whom [illegible] What is stated with regard [illegible] What [illegible] What is a substance said to be [illegible] What is [illegible] negatively electri-[illegible] What does [illegible] more than [illegible] [illegible] called?

Art. [illegible].—[illegible] of electricity divide [illegible] What are they?

Art. [illegible].—[illegible] with regard to the communication of the elec-[illegible] What all substances [illegible] What bodies are called con-[illegible] What [illegible] are called non-conductors? What has [illegible] with regard to electrics and non-[illegible] electrics or non-conductors? [illegible] What substances are [illegible] What substances are mentioned [illegible]

Art. [illegible].—[illegible] substance [illegible] be insulated? [illegible]

Art. [illegible].—[illegible] communication is made between a conductor and [illegible] When is [illegible] from the excited substance [illegible] When is it said to be charged? When [illegible] by means of any conducting substance, [illegible] more than its natural share of the [illegible] which will [illegible] of this peculiar quality [illegible] What illustration of this is given? [illegible] this kind of conducting substances be [illegible]

Art. [illegible].—What is [illegible] mode of exciting electricity? What illustration of this is given?

Art. [illegible].—What is [illegible] glass called? What is [illegible] called?

Art. [illegible].—What is stated with regard to positive and negative electricity? What follows when one side of a metallic or other conductor, receives the electric fluid? What follows when an electric is presented to an electrified body? What follows when two surfaces, oppositely electrified, are united?

Art. 257.—How do similar states of electricity act on each other? How do dissimilar states act on each other? Give the examples.

Art. 258.—For what is the Leyden jar used?

Fig. 123. What does Fig. 123 represent? What is a Leyden jar? When is the Leyden jar said to be charged? How can the jar be discharged? Can an insulated jar be charged?

Art. 259.—Of what is an electrical battery composed? How are the inner coatings of the jars connected together? How are the outer coatings connected? In what way is the battery charged?

Art. 260.—What is the jointed discharger?

Fig. 124. What does Fig. 124 represent? Of what does it consist?

Art. 261.—What is necessary when a charge of electricity is to be sent through any particular substance?

Art. 262.—In what way do metallic rods, with sharp points, attract the electric fluid? How can the electricity be made to pass off silently? Upon what principle are lightning-rods constructed? When is electricity said to be communicated by induction?

Art. 263.—When is electricity produced by transfer?

Art. 264.—For what purpose is the electrical machine constructed? Upon what principle are all electrical machines constructed?

Fig. 123.

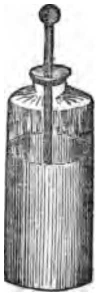
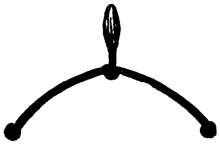


Fig. 124.



How is the electricity excited? Of what is the amalgam composed? In what form is the glass surface made? When is the machine called a plate machine? When is it called a cylinder machine?

Fig. [illegible]. What does Fig. [illegible] represent? Explain the figure. Explain the operation of the machine. To what must the chain be attached when positive electricity is required? To what must it be attached when negative electricity is wanted? What is the first experiment mentioned with the electrical machine? What does the word electrometer mean? Of what does it sometimes consist? What is an electroscope? What is the second experiment? What is the third? What does this show? What is the fourth? What is the fifth?

Fig. [illegible]. What is the sixth? What is the seventh? How may the jar be filled with negative electricity? What is the eighth? What is the ninth? What is the tenth?

Fig. [illegible]. What is the eleventh? What is the twelfth?

Art. [illegible].—What is the universal discharger? What is its use?

Fig. [illegible]. What figure represents it? Of what does it consist? What is necessary in using the universal discharger? What is effected by this means? What experiments are shown by means of the universal discharger? How must the substance be placed? How may ether or alcohol be inflamed?

Art. [illegible].—What are the electrical bells?

Fig. [illegible]. What figure represents them? What are they designed to show? How are they to be applied?

Fig. [illegible]. Explain the spiral tube.

Fig. 125.

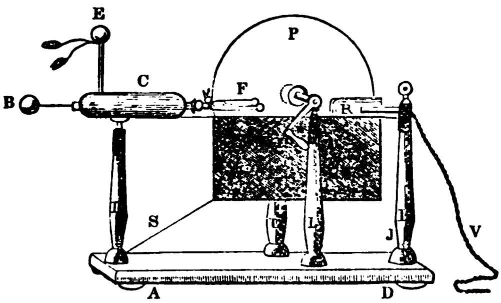


Fig. 126.

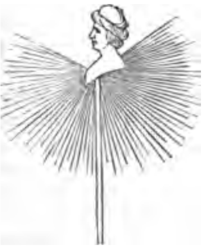


Fig. 127.

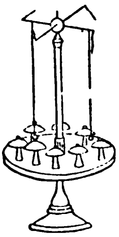


Fig. 128.

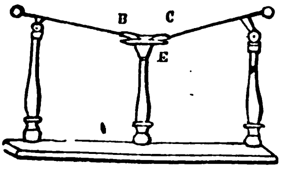


Fig. 129.

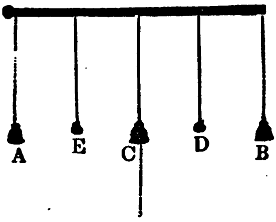


Fig. 130.

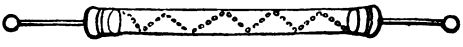


Fig. 131. Explain the hydrogen pistol.

Fig. 132. What does Fig. 132 represent?

Fig. 133. Explain Fig. 133.

Explain experiment one.

Fig. 134. Explain the second experiment. The third.

Fig. 135. Explain the fourth experiment. The fifth. The sixth. The seventh. What is lightning? What is thunder? How is the aurora borealis supposed to be caused? How is the electricity which a body manifests by being brought near to an excited body, without receiving a spark from it, said to be acquired? When an insulated, but unelectrified conductor, is brought near an insulated charged conductor, what is said with regard to the end near the excited conductor? What example is given to illustrate this? Why are square rods better than round ones to conduct electricity silently to the ground, and thus protect buildings from lightning? How far beyond the rod do lightning-rods afford protection? In what way are the most approved lightning-rods constructed? What is remarked with regard to the terms negative and positive? How can this be illustrated? What is said with regard to the time the electric fluid occupies in its passage through its circuit? What example is given to show that the fluid prefers the best conductors? In what different ways does the electric fluid sometimes pass in thunder-storms? Why is it unsafe, during a thunder-storm, to take shelter under a tree, or to hold in the hand any edge-tools? What position is the safest in a thunder-storm? When is there no danger to be apprehended from the lightning? By whom were lightning-rods first proposed? Who first discovered that thunder and lightning are the effects of electricity?

GALVANISM, OR VOLTAIC ELECTRICITY.

Art. 267.—What is Galvanism? By whom and when was galvanism discovered? What led to the discovery? How is electricity generally produced? How is galvanic electricity produced? How does the motion of the galvanic fluid, excited by galvanic power, differ from that explained in the science of Electricity? What bodies are most easily affected by the galvanic fluid?

Art. 268.—How is the galvanic fluid or influence excited? What illustrations of this are given?

Art. 269.—Into what are the conductors of the galvanic fluid divided? What substances are perfect conductors? What substances are imperfect conductors?

Art. 270.—What is necessary in order to produce galvanic action?

Art. 271.—Of what is the simplest galvanic circle composed? What process is usually adopted for obtaining galvanic electricity? Fig. 136. Illustrate this by Fig. 136. What effect will be produced if,

Fig. 131.

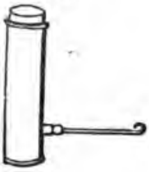


Fig. 133.

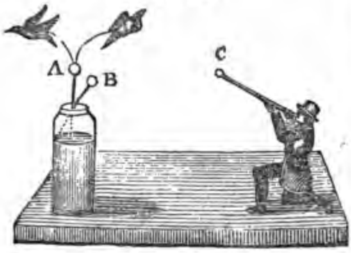


Fig. 132.

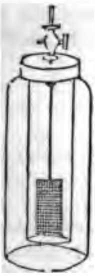


Fig. 134.

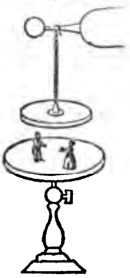


Fig. 136.

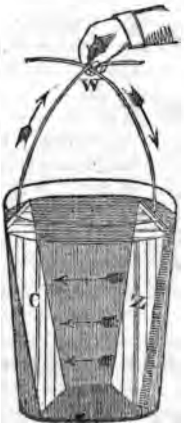


Fig. 135.

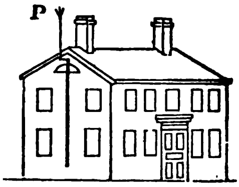


Fig. 144. Describe Grove's battery. Which is the most powerful battery? For what is it used?

Art. 275.—What effects may be produced by a spark from a voltaic battery? What precaution is taken in regard to the lines of the circuit?

Art. 276.—In how many ways does the electricity produced by the galvanic or voltaic battery differ from that obtained by the ordinary electrical machine? What is the first? What is here meant by intensity? How does the quantity of electricity obtained by galvanic action compare with that obtained by the machine? To what may the action of the electrical machine be compared? To what may the galvanic action be compared? What is the second way in which they differ? What is the third? What is said in the note with regard to the third circumstance in which the electricity obtained by the ordinary electrical machine differs from that produced by the galvanic battery? What is said of the effects of this continued current on the bodies subjected to its action?

Art. 277.—On what does the effect of the voltaic pile on the body depend? What facts in common life does galvanism explain? On what does the effects of galvanic action depend? What are batteries constructed of large plates sometimes called? Why? Describe them. Upon what principle is the calorimotor constructed? Are galvanic batteries of value?

MAGNETISM AND ELECTRO-MAGNETISM.

Art. 278.—Of what does Magnetism treat? How many kinds of magnets are there? What are they? What is the native magnet? What property does it possess? What is an artificial magnet? What magnet is preferred, for all purposes of accurate experiment? How can an artificial magnet be made?

Art. 279.—What is the first property of the magnet? Second? Third? Fourth?

Art. 280.—What is meant by the polarity of a magnet? Where is the attractive power of a magnet the strongest? When will a magnet assume a position directed nearly north or south? What is the north pole of the magnet? What is the south pole? In what ways can a magnet be supported so as to enable it to manifest its polarity?

Art. 281.—How do the same and different poles of a magnet affect each other? What is said with regard to the attraction of magnets, whether native or artificial? What analogy is there between the attractive and repulsive powers of the different kinds of electricity, and the northern and southern polarities of the magnet?

Art. 282.—Can a magnet communicate its properties to other bodies? To what substances, only, can these properties be conveyed? Of what substances are all natural and artificial magnets, as well as the bodies on which they act, composed? How can the powers of a magnet be increased? What is a horse-shoe magnet? How can it be made to sustain a considerable weight? What is this bar called? How does soft iron differ from hardened iron, with respect to its acquiring and losing the magnetic power?

Art. 283.—What effect is produced when a magnet is broken or divided? Why is this a remarkable circumstance?

Art. 284.—Where does the magnetic power of iron or steel wholly reside? In what particulars do magnetism and electricity resemble each other? What is the first? What is the second? What is the third? What is the fourth?

Art. 285.—What effect has heat on the power of the magnet? By what is the magnetic attraction diminished? What effect has electricity on the poles of a magnet? What effect has electricity sometimes on iron and steel?

Art. 286.—What proportion do the effects produced by two magnets, used together, bear to that of either, used alone? What is meant by the inclination or dipping of the magnet?

Art. 287.—Does the magnet, when suspended, invariably point to the north and south points? What advantage has the science of magnetism rendered to commerce and navigation? Of what does the mariner's compass consist? To whom is the invention of the mariner's compass usually ascribed? How may the value of this discovery be estimated?

Fig. 144.

Art. 288.—Where are the north and south poles of a magnet the most powerful? What effect has a magnet on a piece of iron, when it is brought sufficiently near to it? How are artificial magnets made? Does the magnet which is employed in magnetizing a steel bar lose any of its power by being thus employed? What is a magnetic magazine? How is a magnetic needle made? What is said with regard to a horse-shoe magnet? How should a horse-shoe magnet be kept?

Art. 289.—Of what does Electro-Magnetism treat? What is the electric current? What does the science of electro-magnetism explain? What is the difference between the currents in the single and the compound circles? What is it thought causes magnetic attraction? What discovery was made in the year 1819? By whom? What further discovery was made soon after, and by whom? What does this philosopher maintain? How many kinds of electricity are there? How do the phenomena exhibited in these five kinds of electricity differ? Can magnetism be developed in steel not previously possessing it? Where must the steel be placed? What property has the uniting wire?

Art. 290.—What are the principal facts in connexion with the science of electro-magnetism? What is the first? What is the second? What is the third? What is the fourth? What is the fifth? What is the sixth? What is the seventh? Where have the bodies been supposed to be placed, in all the effects of electricity and galvanism that have hitherto been described? What is the eighth fact in connexion with the science of electro-magnetism? What is the ninth? What is the tenth? How can the direction of the electric current be ascertained?

Art. 291.—If a magnet be freely suspended, and a current of electricity be passed near it, what direction will it assume? What illustration of this is given? What second illustration is given? In what direction will the pole of the needle next to the negative end of the wire move, if the connecting wire be placed below the plane in which the needle moves, and parallel with it? What is said with regard to the attractions and repulsions?

Art. 292.—How may the two sides of an unmagnetized steel needle become endued with the north and south polarity? Under what circumstances will it become permanently magnetic?

Art 293.—How can magnetism be communicated to iron and steel? How can the effect be more conveniently produced? What illustration of this is given? What is the helix? Why should the wire, which forms the helix, be coated with some non-conducting substance? What is said of a helix, if it be placed so that it may move freely?

Art. 294.—How can the magnetic needle be made to deviate from its proper direction? What is a needle thus prepared called?

Art. 295.—What is the electro-magnetic rotation? What illustration is given?

Fig. 145. What does Fig. 145 represent? Explain the figure. How is the freedom of motion, which is required on the wire, obtained? How can the metallic contact which is required be obtained? If the poles of a battery be connected with the horizontal external wires, *c c*, throughout, what direction will the current of electricity take? Round what pole will the moveable part of the wire rotate? Round what will the magnetic pole rotate?

Fig. 146. What does Fig. 146 represent? Of what does it consist? How will the cylinders in each revolve, if, instead of a bar-magnet, a horse-shoe magnet be employed, with an apparatus on each pole similar to that which has now been described?

Fig. 145.

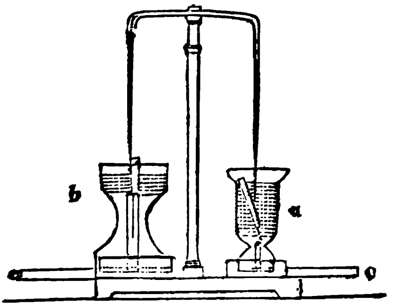
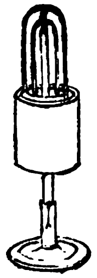


Fig. 146.



Art. 296.—How may the magnetizing power of the connecting wires be increased? Is a single circuit preferable to a straight wire?

Fig. 147. Explain Fig. 147.

Art. 297.—What is a bar called that is temporarily magnetized? How do you ascertain the poles of an electro-magnet?

Art. 298.—How have magnets of great power been formed? What weight was the magnet constructed by Professor Henry and Dr. Ten Eyck capable of supporting?

Fig. 148. Explain the heliacal ring and Fig. 148

Art. 299.—How are bars of the U form most readily magnetized?

Fig. 147.

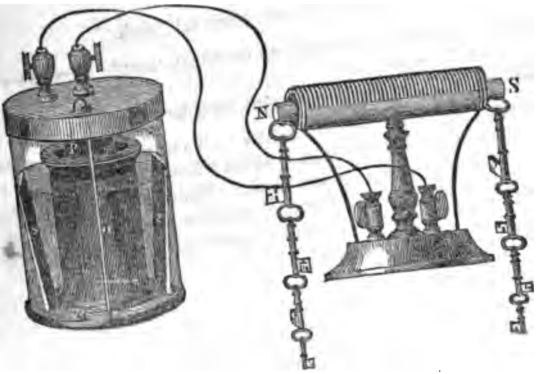


Fig. 148.

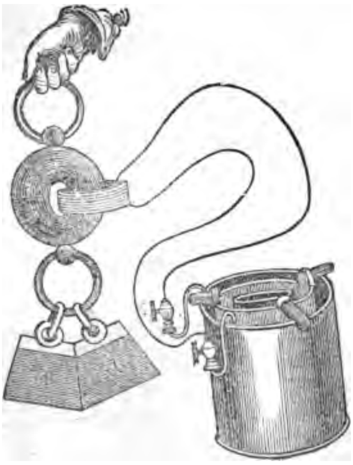


Fig. 149. Explain Fig. 149.

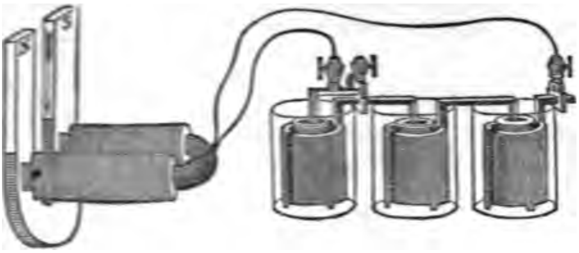
Art. 300.—Explain the electro-magnetic telegraph.

Art. 301.—Of what does magneto-electricity treat? How are electric currents excited?

Fig. 150. Explain the magneto-electric machine, Fig. 150.

Art. 302.—What is thermo-electricity? To what do the magnets owe their peculiar properties? What follows from this? How many states of electricity are there? What is said of that derived from the common electrical machine? What is said of that derived from the galvanic apparatus? What is said of the thermo-electric currents?

Fig. 149.



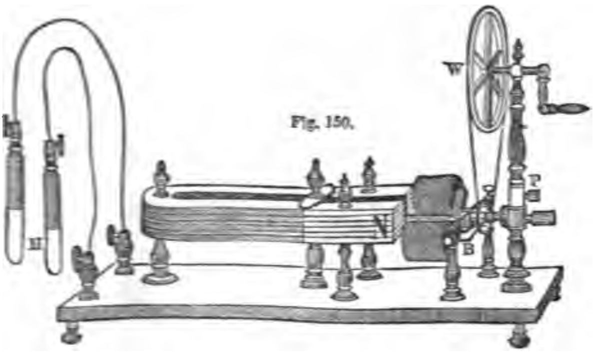


Fig. 150.

ASTRONOMY.

Art. 303.—Of what does Astronomy treat? What is said of the earth? How is the earth known to be round? Where is it situated?

Art. 304.—Of what does the solar system consist? What are the stars supposed to be? Do we see more by the aid of glasses than without?

Art. 305.—How may the planets be distinguished from the stars? How are the planets distinguished from the *fixed* stars? What is the meaning of the word planet? Why are they called planets? What are the fixed stars? What are the sun, moon, planets, and fixed stars supposed to be? Why do they appear so small? What has been stated with regard to the attraction of portions of matter? Upon what force does this attraction depend? What follows from attraction being mutual? What direction do bodies take when actuated by several forces? Is this true with regard to the heavenly bodies? What is the centre of the solar system? What is said of the revolution of the planets?

Art. 306.—What are the paths in which the planets move around the sun called? Around what do the planets revolve? What is a year on each planet? How long is the year of the planet Mercury? How long is the planet Venus performing her revolution around the sun? How long is the earth performing her revolution around the sun? What is the length of the year on the planet Mercury? Venus? Earth? Mars? Vesta? Juno? Ceres? Pallas? Jupiter? Saturn? Herschel? Neptune? Of what form are the orbits of the planets? What is meant by the mean distance? What planets are called *inferior*? Why? What planets are called *superior*? Why? What is the distance of the planet Mercury from the sun? Venus? Earth? Mars? Vesta? Juno? Ceres? Pallas? Jupiter? Saturn? Herschel? Neptune? Have the planets any motion besides that around the sun? What is the time in which they turn upon their axes called? What is the length of a day on the planet Mercury? Venus? Earth? Mars? Vesta? Juno? Ceres? Pallas? Jupiter? Saturn? Herschel? Neptune?

Art. 307.—What is the diameter of the Sun? Mercury? Venus? Earth? Mars? Vesta? Juno? Ceres? Pallas? Jupiter? Saturn? Herschel? The Moon?

Fig. 151. What does Fig. 151 represent? What illustration of the comparative size and distance of the bodies of the solar system is given? What is necessary in order to imitate the motions of the planets in the above-mentioned orbits?

Art. 308.—What is the ecliptic? Why is it called the ecliptic?

Art. 309.—What is the zodiac? Why is it called the zodiac?

Art. 310.—What are the names of the twelve constellations? How many degrees does each sign contain?

Art. 311.—Are the orbits of the other planets in the same plane with that of the earth?

Fig. 152. What does Fig. 152 represent? What are the nodes of a planet?

Fig. 153. What does Fig. 153 represent?

Art. 312.—When is a planet said to be in any particular constellation?

Art. 313.—What do the perihelion and aphelion of a heavenly body express? When is a body said to be in its perihelion? When is a body said to be in its aphelion? How much nearer is the earth to the sun in its perihelion than in its aphelion? When is a planet said to be in its inferior conjunction? When is it said to be in its superior conjunction? When is it said to be in opposition?

Art. 314.—What do the apogee and perigee of a heavenly body express? When is a body said to be in its perigee? When is it said to be in its apogee?

Fig. 151.

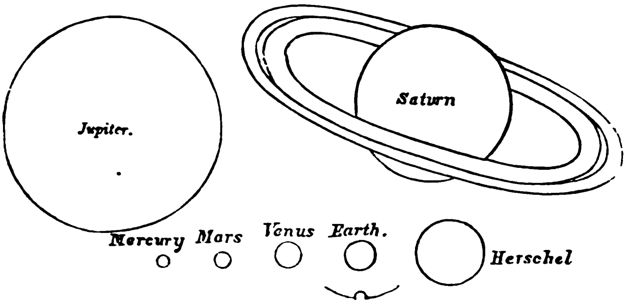


Fig. 152.

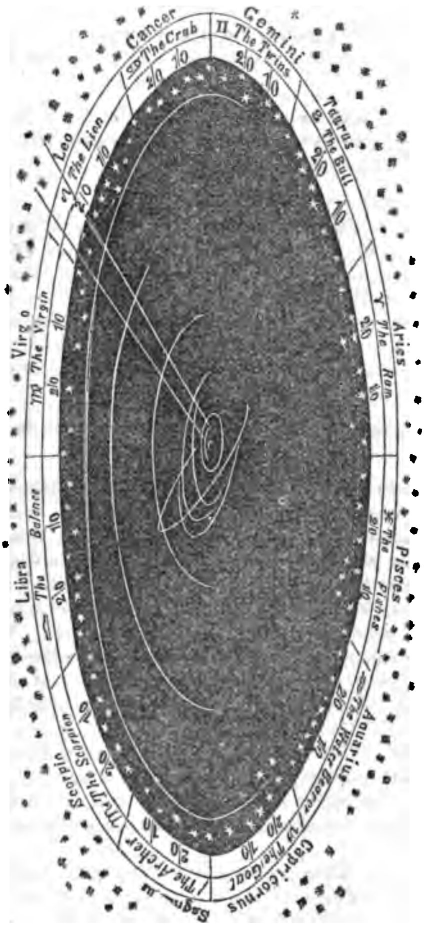
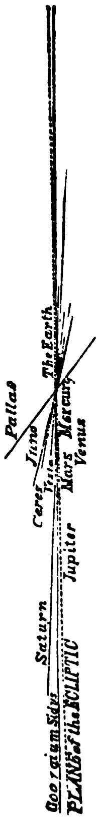


Fig. 153



ART. 315.—In what sign is the perihelion of the planet Mercury? Venus? Earth? Mars? Vesta? Juno? Ceres? Pallas? Jupiter? Saturn? Georgium Sidus?

ART. 316.—What is said with regard to the axes of the planets in their revolution around the sun? What does this inclination of their axes cause?

ART. 317.—What is said with regard to the motion of the heavenly bodies? When do they move with the greatest velocity? When is their motion the slowest?

ART. 318.—What is Kepler's law?

Fig. 154. Illustrate this by Fig. 154. Explain, by Fig. 154, the reason why the earth, or any other heavenly body, moves with a greater degree of velocity in its perihelion than in its aphelion. What is said of the motion of the heavenly bodies from perihelion to aphelion? What is their motion from aphelion to perihelion? When is their velocity the greatest? How much longer is the earth in performing the aphelion part of its orbit than the perihelion part?

ART. 319.—How much nearer is the earth to the sun in winter than in summer?

ART. 320.—What follows from the inclination of the earth's axis, with regard to the direction of the sun's rays? When is the heat always the greatest? What is said of oblique rays? What is the reason that the heat is greater in summer than in winter?

Fig. 155. Illustrate this by Fig. 155. How is the earth situated with regard to its distance from the sun in winter? What illustration of oblique and perpendicular rays is given in the note? Why is it generally cooler early in the morning and late in the afternoon than at noon? Why is the heat the greatest at about three o'clock? What causes the variety of climate in different parts of the earth? Where does the sun always shine in a vertical direction? What would follow were the axis of the earth perpendicular to its orbit? What causes the variety of the seasons, the different lengths of days and nights, &c.? What is necessary in order to understand the illustration of the causes of the seasons?

Fig. 156. Explain Fig. 156. What are the poles? Why is the circle I K called the tropic of Cancer? What is the meaning of the word tropic? Why is the circle L M called the tropic of Capricorn? What are the tropics? What is the circle E F called? What does it represent? What is the circle G H called? What does it represent?

Fig. 154.

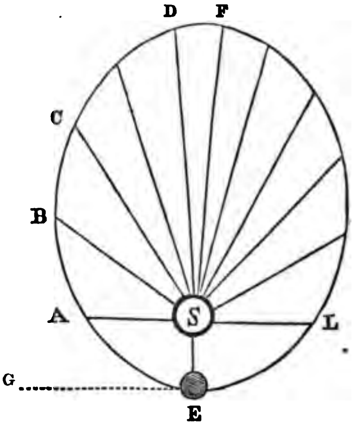


Fig. 155.

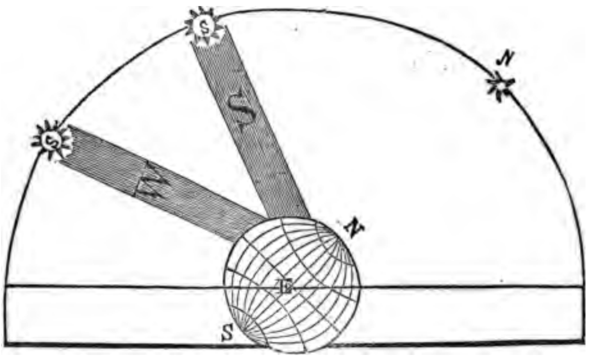


Fig. 156.

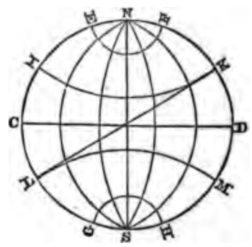


Fig. [illegible] What does Fig. [illegible] represent? Explain the figure. Explain, by the figure, the situation of the earth on the 21st of June. What causes day and night? To what part of the earth is it day? To what part is it night? To what is the length of the day in proportion? When are the days the longest? Why? When are they the shortest? Why? Explain, by the figure, the situation of the earth on the 23d of September. On the 23d of December. On the 20th of March. What follows from the changes in the earth, caused by the inclination of the earth's axis? In what proportion are these changes? What is said of the axis of the planet Jupiter? Is it supposed that the sun, planets, and stars are inhabited? What is shown by Fig. [illegible]? Where are these points? What are they called? Which is the vernal equinox? Which the autumnal? What other two points are there? Why are they called solstices? Where are these points? Which is the summer solstice? Which the winter?

Art. 321.—What is said of the sun? What is its diameter? How much does its cubic magnitude exceed that of the earth? How long is it in performing its revolution around its axis? How has this been ascertained? What did Dr. Herschel suppose these spots to be? What is the zodiacal light? At what time is it most distinct? Where is it constantly visible?

Art. 322.—What planet is nearest to the sun? Why is it seldom seen? What is said of the heat of this planet? How much greater is the sun's heat in Mercury than on the earth? In what form does water exist in Mercury? How can Mercury be recognised when seen? At what time does it appear? How does Mercury appear when viewed through a telescope?

Art. 323.—What planet is nearest to the earth? When is Venus called the morning star? When is it called the evening star? How much greater are the light and heat at Venus than that at the earth? What name was given by the ancient poets to Venus, when morning star? What, when evening star? What is the greatest distance at which the planets, Mercury and Venus, ever appear from the sun? What is meant by the transit of these planets? What is said of the different appearances which Venus presents? Why can we not see the planets and stars in the daytime?

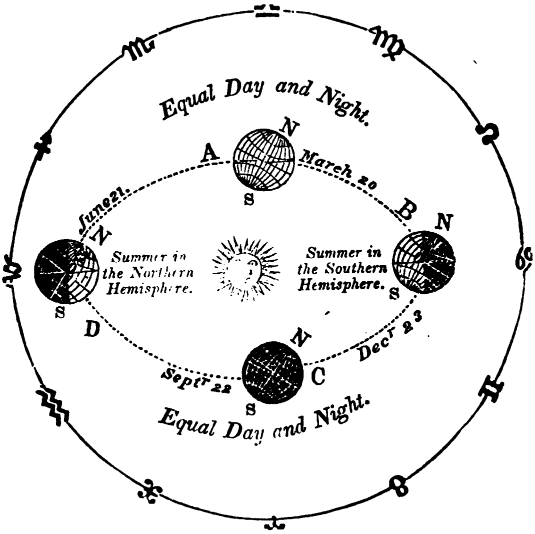
Art. 324.—What planet is next to Venus? What is the form of the earth? How much larger is its equatorial diameter than its polar? How many moons has the earth? What is the diameter of the moon? What is its distance from the earth? What is the length of a day at the moon? How long is it in performing its revolution around the earth?

RT. 325.—What phases does the earth, when viewed from the moon, exhibit? How much larger does the earth appear than the moon?

RT. 326.—What planet is next to the earth? What renders it conspicuous? What is supposed to cause this appearance? How much more light and heat does the earth enjoy than Mars? When were the asteroids discovered? By whom, and in what year was Vesta discovered? What is the color of its light? By whom and when was Juno discovered? What is the color of its light? When was Pallas discovered? By whom? What is said of its atmosphere? When and by whom was Ceres discovered? What is its color? What is said in the note with regard to these planets?

RT. 327.—Which of the planets is the largest? How much more light and heat does the earth enjoy than Jupiter? How many moons has this planet? What is the distance of these moons from the planet? In what time do they perform their revolu-

Fig. 157.



move around the planet? How does the size of these moons compare with that of ours? Why has Jupiter no sensible variety of seasons? Of what use are the eclipses of Jupiter's moons? How long is light in coming from the sun to the earth? How has this been ascertained? How does Jupiter appear when viewed through a telescope?

Art. 328.—How does Saturn compare in size with the other planets? How is Saturn distinguished from the other planets? What is said of these rings? How much longer are these rings in performing their revolution around the planet than the planet is in performing its revolution on its axis? What is the breadth of these rings? What is said of the surface of Saturn? How many moons has Saturn? How may Saturn be known? What is said of the moons of Saturn? Why are they not often observed?

Art. 329.—How does Uranus compare in size with the other planets? How does the light and heat at Uranus compare with that of the earth? By whom was this planet discovered? What name did he give it? How many moons has Uranus? By whom were they discovered? How are their orbits situated, with regard to that of the planet? What is said of their motion? What appears to be a general law of satellites? What follows from this with regard to the appearances which the inhabitants of the secondary planets must observe?

Art. 330.—Who discovered the planet Neptune?

Art. 331.—What is the meaning of the word comet? To what class of bodies is this name given? Of what do these bodies appear to consist? What is the number of comets that have occasionally appeared? What discoveries have been made concerning 98 of them? What is the result? What is the form of the orbits of comets? What is said of the motion of comets when in perihelion? What did Newton calculate the velocity of the comet of 1680 to be in an hour? For what was this comet remarkable? What is said of the luminous stream of a comet as it approaches and recedes from the sun? What did Newton, and some other astronomers, consider the tails of comets to be? What is said in the note with regard to comets? Who were the first astronomers that successfully predicted the return of a comet? What is the periodical time of Halley's comet? Of Encke's? Of Biela's?

Art. 332.—Into how many magnitudes are the stars classed? Of what magnitude are the largest? Of what are the smallest? What are telescopic stars? Why cannot the distance of the fixed stars be determined? To what is the difference in their apparent magnitudes supposed to be owing? Have the stars any motion?

Art. 333.—What is the Galaxy? Of what is it supposed to consist? How did the ancients divide the stars? What was the number of constellations among the ancients? How many have been added by the moderns? How are the stars designated on the celestial globe? What is the situation of each constellation now? Illustrate this. What is the cause of this difference? Why do we not see the stars, and other heavenly bodies, in their true situation? How can a star be seen in its true situation? What is meant by the aberration of light? What is necessary to be taken into consideration, in determining the true place of the celestial bodies? What effect has this property of the atmosphere on the length of the days?

Art. 334.—What is the parallax of a heavenly body?

Fig. 158. Explain Fig. 158. What appears from this? What allowance must also be made?

Art. 335.—Is the moon a primary or secondary planet? How long is it in performing its revolution about the earth? What is its distance from the earth? What is the most obvious fact in relation to the moon? How is this caused? What kind of a body is the moon? By what light does it shine?

Fig. 158.